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THE JOURNAL OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

· SEPTEMBER · 1916 ·

ANNUAL MEETING, NEW YORK CITY, DECEMBER 5-8

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TO EVERY MEMBER

THE last day on which papers for the forthcoming Annual Meeting will be accepted for consideration is September 20. Papers received after this date will be considered for local meetings or for the Spring Meeting, 1917.

Papers and discussions are the basis of the professional activities of the Society, and members should contribute without reserve from their experience, and should urge their fellow-members to do the same.

For the realization of our ambition to make our Journal and Transactions a professional necessity to every mechanical engineer, members should feel an obligation to devote their knowledge, data, skill and experience through these channels of the Society to the benefit of their profession.

The tendency in American industries is to commence manufacture and establish it on an organized basis without much research into the literature of the subject, in contradistinction to the more efficient methods of thoroughly mastering existing data in advance. The effort of the Society—the Society of the Industries—is to solicit specific information and encourage its application to manufacture as a means of building up the industrial supremacy of our nation.

Members of the Society have the knowledge and experience, and they are urged to realize that their opportunities for service to the engineering profession, and to the nation at large—and reciprocally the rewards for service—were never greater than now.

The Annual Meeting

New York, December Fifth to Eighth

IN the two preceding issues we were able to announce the topics proposed for two of the sessions of the thirty-seventh Annual Meeting—the all-day Session on Valuation of Industrial Property, and the Gas-Power Session. Below are given proposed features of other sessions.

Railroad Session

Three papers on the following subjects: Pulverized Fuel for Locomotives. Clasp Brakes. The Mechanical Design of Electric Locomotives.

Machine Shop Practice Session

Session on Standardization of Machine Tools, to include two papers on this subject. Also paper on a plan of action for the Sub-committee on Machine Shop Practice.

Textile Session

Three papers, subjects to be announced.

Industrial Building Session

Paper on the Design of Commercial Buildings.

Miscellaneous Sessions

For these sessions eight papers have already been accepted. Other papers received are now being examined, and additional papers are expected during the month.

Plans for the social and other features of the meeting are also well under way, as announced in the Society Affairs Section of this issue, and the anticipations are that the forthcoming Annual Meeting will be a record one.

ESTABLISHING A STANDARD OF MEASUREMENT FOR NATURAL GAS IN LARGE QUANTITIES

By FRANCIS P. FISHER, BARTLESVILLE, OKLA.

Member of the Society

THE original business of natural gas handling and selling was confined to the discoverer, or owner, taking the gas from his own wells through his own pipes to various purchasers, and supplying them, in consideration of certain fixed monthly payments, with all the gas they could use. This eliminated the whole problem of gas measurement.

Some twenty years ago this simple and effective solution became impossible because of its extravagance, and the familiar domestic meter of the artificial gas business was slightly modified to take care of the domestic and small industrial consumer of natural gas. The operation of these meters is based on actual displacement from alternate filling and emptying chambers, and is comparatively simple. Where properly cared for and installed, these meters have given continuous measurements well within the commercial limits of required accuracy over long periods of time.

The discovery of new gas fields has been practically a continuous process, and many fields were opened up in the vicinity of towns previously piped for artificial gas. In time, selling contracts were made between the owners of gas wells and the artificial gas companies already equipped to serve domestic consumers, the sale of gas being effected at the town border. Also, large industrial consumers were connected up to gas lines and took gas in quantities too large to measure by the standard type of meter, leading to suggestions of many devices for taking care of the measurement of these larger quantities.

Today, approximately two and a half million people in this country make or receive a monthly settlement based on the measurement of natural gas. The gas must be handled from its original location in the gas-bearing rock strata to its point of consumption without being seen or weighed. The basis on which the gas changes ownership at various periods during its handling consists of indications on dials and charts of various apparatus; and in numerous cases where the faith of one or both parties in these indications is insufficient, the quantity of gas which has changed owners must be settled by arbitration and compromise.

AVAILABLE MEANS OF MEASUREMENT

While very accurate, the large wet meters used for station meters at the producing plants of artificial gas companies, by reason of size, cost and care required for operation, were not adapted to the much larger quantities of lower-priced gas handled in the new industry. The measuring devices suggested to meet this problem, up to within the last three or four years, were of three general classes: *a* proportional meters; *b* pitot tips in ordinary pipe lines; and *c* calibrated tubes containing pitot tips.

The proportional meter is simple and ingenious in principle. The gas passing through this meter is divided automatically into a large and a small channel, each having a definite ratio of resistance to the gas flow, so that the quantities of gas passing through the two channels have a fixed ratio, varying from 1/50 to 1/200 according to the size of the meter. The smaller quantity is measured by an ordinary domestic meter with a multiplying dial register.

If the gas to be measured had been a clean, pure, perfect gas, it is probable that proportional meter records would have been satisfactory. However, to the initial mechanical difficulties of devising such a meter were added difficulties caused

SYNOPSIS

This paper deals with the methods employed by a company operating over 1200 miles of pipe lines in the mid-continental gas field, in establishing a standard of measurement for natural gas in large quantities.

After pointing out the commercial importance of such a standard, the author describes the various available means of measurement—proportional meters, pitot tips in ordinary pipe lines, calibrated tubes containing pitot tips, the Thomas meter, the orifice meter, etc., stating their respective advantages and shortcomings. He then takes up a specific problem of loss in the system mentioned, and in selecting a point of attack, chooses the large-capacity measurements with orifice meters as promising quicker results for a given amount of work, and for the reason that such meters do not involve delicate mechanism or the employment of complex formulae.

Some serious inconsistencies which developed after the first two months' operation were attributed to fundamental error of some kind in the principle employed, and the basic assumptions of the method were accordingly subjected to verification in several ways, the quantity of gas metered being taken as equal to the sum of the gas lost by leakage, the gas added to or taken from line by change of pressure, and the gas compressed.

All of the orifice calibration work has been compiled and plotted in a chart which gives the velocity coefficient for all sizes of pipe on a basis of ratio of diameter of orifice to diameter of pipe, and the author believes that the fair curve through the plotted points gives values that may be safely applied to any practicable size of pipe line; they are now actually in use on the system in question.

In the course of the work it was found necessary to develop a differential recording gage to eliminate certain operating difficulties, the outcome being a special type of mercury float gage, particulars of which are given in the paper.

It has been found impossible to obtain accurate measurements with a pulsating flow of gas, this being particularly true when the pulsations are rhythmic, as in the vicinity of compressor stations. As numerous attempts to measure under such conditions have been unsuccessful, efforts are now being directed toward the elimination of pulsation, and one device which seems promising is described.

In the discussion, the attitude and regard for scientific accuracy displayed by the author's company were commended, and attention was called to the fact that two independent sets of investigations as to the variation of natural gas from the laws of perfect gases are now in progress. The hope was expressed that some body, such as the Society, working in conjunction with the Bureau of Mines, the Bureau of Standards, the state universities and others, would correlate the work of various investigators and establish uniformity in the constants or coefficients, in the types of apparatus to be used in the determination of specific gravity and measurement of gases, and in differential pressure-recording instruments.

Presented at the Spring Meeting of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, New Orleans, La., April, 1916. Pamphlet copies of complete paper without discussion may be obtained; price 15 cents to members, 30 cents to non-members.

by dust and sand from the rock formation, water, salt, oil and gasoline from the wells, dirt left in the pipes when the line was laid and small bits of debris from the same source, including occasionally portions of carcasses of animals that ventured into the lines during construction, and in winter time, quantities of hoar frost forming on the inside of the pipe line, and moving along with the gas whenever the temperature rose sufficiently to loosen the frost from the pipe. The number of competent men in this country today, trained to adjust and calibrate these meters, is wholly inadequate to secure a continuous and satisfactory record of the gas to be measured. The best condition for proportional meter operation is in the distribution plant, a long distance from the fields, where the gas has passed many drips and cleaning devices and is comparatively clean. The most unpropitious location is in the fields close to the wells.

The pitot tube furnishes a more certain and dependable method of measurement of very large quantities, and has been widely used in various forms. There are two general types of installation: The first consists of inserting pressure and velocity tips in the ordinary pipe line through a tap made for the purpose, assuming an average velocity at a given distance from the circumference (taken at various values by different

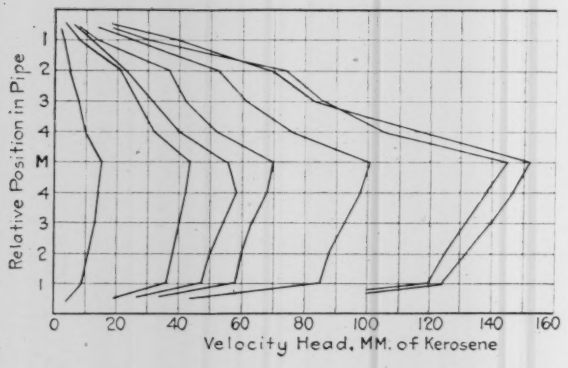

FIG. 1 PITOT TUBE TRAVERSE, 8-IN. PIPE

writers). The quantity of gas passing is measured by observing the difference of pressure between static and velocity tips, and calculating the quantity passed by the fundamental pitot tube formula $V = \sqrt{(2gh)}$. The fundamental weakness of the formula is that a different and unknown coefficient should be applied to each individual installation to take care of the slight variation from nominal diameter and the effect of roughness of the pipe. The coefficient is also modified by irregularity of velocity in the same zone, shown by the erratic results obtained in different pipe traverses where the velocity tip (or both tips) is stationed progressively at regular intervals across the diameter of the pipe, and observations plotted to show the variations in velocity at different distances from the center. (See Fig. 1.)

The second and more refined form of installation of the same instrument—for many years considered the standard for large-quantity measurements—consists of tubes of polished brass carefully compared with similar standardized tubes and the coefficients determined by experiment. This instrument has been fully described by Thos. R. Weymouth[1] and B. C. Oliphant.[2]

[1] Measurement of Natural Gas, T. R. Weymouth, Trans. Am.Soc.M.E., vol. 34, p. 1091.

[2] Proc. Nat.Gas.Assn. of America, vol. 4, p. 212.

These tubes at their best are capable of giving very close results. They are calibrated by experiment individually, and each one, therefore, is liable to have a coefficient varying slightly with the personal equation of the man making the test. In actual practice the tubes are occasionally found not to run harmoniously in tandem on the same quantity of gas. Only recently have satisfactory differential gages been devised for recording automatically the observed differential pressures used in the formula for computing the quantities. It was, therefore, found necessary to have these meters installed at regular 24-hr. operating points and the gage readings recorded generally at 15-min. intervals by observers, thus bringing another personal equation into the result. The long piping usually installed from these tubes to the observing station would show a material effect on the indication from small leakages. In many cases also it was found that sand or salt lodged against the velocity opening, partially or wholly closing the exposed tip, again affecting materially the indication without the knowledge of the observer. In one case a small tin can hung itself neatly over the velocity tip and put an important measuring station temporarily out of commission.

MORE RECENTLY SUGGESTED MEANS OF MEASUREMENT

In the last few years additional standards of measurement which promise a distinct advance have been proposed. The Thomas electric meter[1] operates on the most ingenious principle of imparting a small quantity of heat to the gas electrically, and maintaining a constant temperature increase between the incoming and outgoing gases. The quantity of gas is directly calculated from the quantity of heat supplied, as measured by the electrical input necessary to furnish the heat. This meter has the great advantage of being theoretically accurate without a specially calibrated coefficient, and also of working independent of the pressure at which the gas passes, giving in effect a measurement of mass. The question arises, however, as to the adequacy of available data on the specific heat of gas of widely varying composition and with daily changes in specific gravity. Its installation involves considerable expense per unit as compared with other types.

The so-called orifice meter is another comparatively recent suggestion. This well-known principle of flow of fluid through a thin-edged orifice is very simple of application to pipe lines, and seems to give promise of good results; but there has been great difficulty in securing recording gages delicate enough to retain their accuracy and rugged enough to keep in continuous operation under severe field conditions,—occasionally withstanding excessive pressures, either forward or backward.

The venturi meter has also been applied to some large and important measurements. The comments above apply practically to the venturi meter with the exception that the range is somewhat wider, the cost of installation is considerably heavier, and a true formula is more complex.

The rotary station meter, quite generally adopted in artificial gas plants, has also been applied recently to a comparatively few installations.

Very delicate and complex apparatus that has proved successful for steam meters in expert hands is wholly impractical under the rough conditions of natural gas measurement.

With the meter difficulties enumerated, for many years most of the gas companies did not attempt a complete measurement of the gas produced from their own wells until it reached the

[1] J. C. Wilson, Proc. Nat.Gas.Assn. of America, vol. 6, p. 219.

point of consumption and sale. But, while the extravagance of the ultimate consumer has been soundly and properly eliminated by selling him gas in measured quantity, the loss of gas between the producing wells and the consumer remains hidden, owing to difficulties of measurement.

Due to various causes, however, in many fields the tendency in recent years has been towards the separation of the ownership of the wells from that of the great pipe-line systems connecting the producing fields with ultimate markets. This has raised an imperative call for field measurement, involving financial settlement, for large quantities of gas taken at the wells. The result is that the comparison of the amount of gas purchased and sold has been forcibly emphasized by its financial aspect, with very surprising results in many cases, showing enormous unaccounted-for losses of gas.

To avoid the difficulty of large quantity measurement, many contracts for sales have been made with separate distribution companies having pipe-line systems, where the supplying company takes a percentage of the domestic meter sales. Thus, the losses in towns themselves were not generally realized. Instances have developed where from 35 per cent to an extreme of 80 per cent of all gas entering town distributing systems appears as unaccounted for in meter sales, and some large pipe-line systems have discovered overall losses approximating 50 per cent of all gas entering the system. In fact, it was discovered recently that losses in excess of 25 per cent are the general rule rather than the exception.

A SPECIFIC PROBLEM OF LOSS

Some three years ago the writer became associated with the reorganized management of a natural gas piping system in the Mid-Continent field, comprising something over 1200 miles of main lines with corresponding field and distributing plants. In the course of investigations preparatory to outlining a general policy, there was discovered between purchase and sales a loss of gas which seemed wholly unreasonable and the elimination of which would be the shortest and most effective road to early increase of earnings.

The total loss could be made up from losses from six possible causes:

1 Leakage of field lines
2 Leakage of main lines
3 Leakage in distribution systems
4 Errors in large-capacity meters
5 Errors in domestic meters
6 Errors in estimates of unmeasured gas

The first step in eliminating this waste was to provide an accurate gas measurement at strategical points, for segregating the leakage so that the repair work could be made efficient. Manifestly, the first problem was that of large-capacity meter installation, and with part of our losses possibly due to meter inaccuracy, the first step was the establishment of a definite standard of accuracy in meters. The work done to establish this standard has been continued by a technical staff for approximately two and one-half years at considerable expense. It has now passed the second phase of installing measuring stations to segregate and locate definitely the remaining leakage losses.

Meanwhile, repairing of the most evident weak places and reduction of 95 per cent of our purchase and 75 per cent of our larger sales to standard bases, have reduced the unaccounted-for losses about one-half, and we are prepared to get after the more difficult remainder with more efficient tools and better promise of quick results. The matter of critical study of domestic meters, believed to be the final step in this campaign, is reserved until other corrections and improvements are initiated and in operation.

POINT OF ATTACK

In selecting a point of attack, the large-capacity measurements were chosen as promising quicker results for a given amount of work. The small-capacity meters as now operated are more reliable, but the number is so great that improvement through checking these meters would necessarily be slow.

In connection with large-capacity measurement, a catalog of the weaknesses and objections to all known and available methods has been given earlier in the paper. It was determined that the relative objections be weighed and one of the systems chosen as a standard to be developed to a closer degree of accuracy than heretofore available. The method chosen for development was the orifice meter, in the belief that the objections to the existing types could be overcome at less cost and more simply than in any of the others. Further consideration was the absence of delicate mechanism, and the simplicity of the formula. There is no question but what any one of the other methods of measurement is capable of an equal degree of refinement, but the present paper is chiefly concerned with the work actually done on this one type of meter.

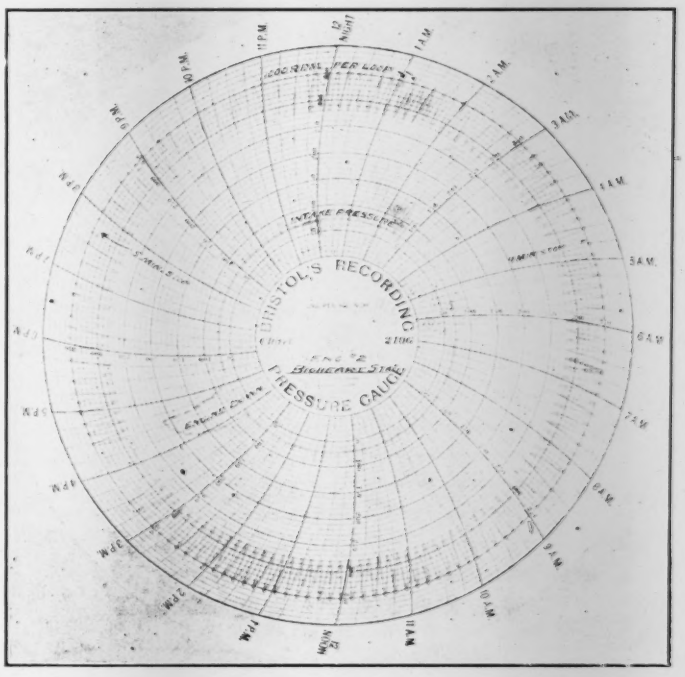

FIG. 2 CHART OF REVOLUTIONS OF COMPRESSOR AND INTAKE PRESSURE

In order to give the work a sound foundation, it was considered necessary to establish a standard of reference entirely independent of existing meter indications, and a 250,000-cu. ft. capacity artificial gas holder at Joplin, Mo., was taken as a reference quantity. This part of the work has been described concisely and accurately in a paper presented to the Society in December, 1915, by E. O. Hickstein. Some 500 standardized flows were made, covering a period of nearly a year, for establishing a wholly independent and authoritative coefficient which could be relied on in actual service. This work was con-

fined to various-sized orifices in 8 and 10-in. pipes, inasmuch as the quantities to be measured first were large and would necessitate such installations.

In the meantime, while these calibrations were being made, the manufacturers of differential recording gages were urged to perfect and deliver recording differential gages having a range of zero to 50 in. water pressure, and operated by an iron float in a mercury U tube. These gages were finally perfected and delivered about the time of the completion of the Joplin tests, and about twenty of the most important installations were made in rapid succession.

ORIGINAL CONSTANTS CALLED IN QUESTION

With the results of these installations, after the first two months' operation some serious inconsistencies appeared which were attributed to fundamental error of some kind in the principle being employed. We considered it necessary at once to verify the following basic assumptions not previously experimented on.

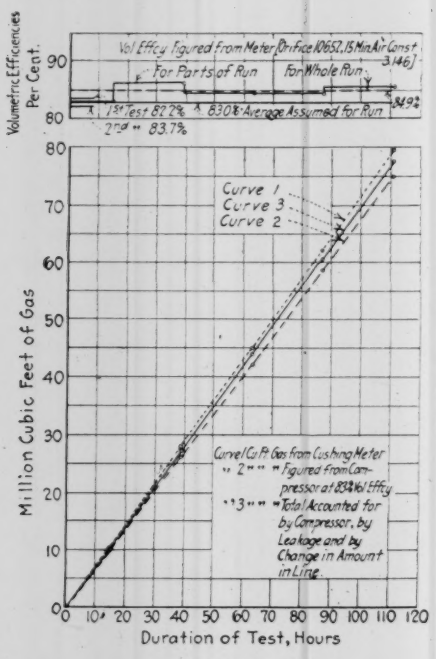
Volumetric Efficiencies Per Cent.
Vol Effcy figured from Meter Orifice 10652, 15 Min Air Const 3.146
For Parts of Run
For Whole Run
1st Test 82.7%
2nd " 83.7%
83.0% Average Assumed for Run
84.9%
Curve 1
Curve 3
Curve 2
Curve 1 Cu Ft Gas from Cushing Meter
" 2 " " figured from Compressor at 83.4% Effcy
" 3 " " Total Accounted for by Compressor, by Leakage and by Change in Amount in Line
Million Cubic Feet of Gas
Duration of Test, Hours

FIG. 3 CURVE SHOWING NET RESULTS OF PUMP STATION DISPLACEMENT TESTS

First Assumption. Coefficients determined by experiments with differentials of 4½ in. of water or less, representing velocities of less than 100 ft. per min., are constant with velocities up to 300 ft. per min., represented by differentials up to 50 in. of water, which were utilized in actual service.

Second Assumption. Coefficients determined at atmospheric pressure are constant and unchanged by static pressures up to 365 lb. absolute.

Third Assumption. Coefficient determined with air at point of saturation is applicable to natural gas by applying correction for specific gravity.

Fourth Assumption. Natural gas is a perfect gas, having pressure and volume relations according to Boyle's law.

The work of verifying these assumptions was undertaken in three ways. The first was by a careful comparison under operating conditions of orifice meter registration with a calibrated compressor displacement.

WORK TO ESTABLISH CONSTANTS

There was available at Bigheart, Okla., a compressor station consisting of three duplex units of about 950 h.p. rating twin-tandem gas engines, each driving two double-acting compressor cylinders with poppet valves, only one engine being used in the test.

Fifty miles distant, near the north end of the Cushing field, was located a measuring station with a 10-in. orifice meter containing a disk with 6½-in. opening. The dimensions of the intervening lines are:

Nom. Diam., In.	Actual I.D.	Area, Sq. In.	Area, Sq. Ft.	Length	Capacity, Cu. Ft.
18 O.D.	17.375	237.10	1.646	42,091	69,300
16 O.D.	15.375	185.66	1.289	79,823	102,900
10 I.D.	10.192	81.585	0.5661	6,747	3,822
12 I.D.	12.250	117 860	0.8185	84,549	69, 90
12 O.D.	1 .4316	102.636	0.7125	28,947	20,630
			Total Cu. Ft.		265,742

The first factor to be determined was the leakage. The line was filled to about 300 lb. and closed in. After the pressure had equalized, the pressures were carefully taken at half-hour intervals until the pressure reached 270 lb. Then the compressors were started and the pressure reduced to 230 lb. After the pressure was equalized again, the pressures were taken as before. In this way the leakage was determined at a number of points, approximately 280, 225, 165, and 115 lb., giving the same results that would have been obtained by allowing the whole volume of gas to leak out. Fig. 4 gives a graphical representation of the pressure log during the leakage test. Fig. 5 was derived from Fig. 4 by plotting to a large scale and drawing a fair curve through the resulting points to eliminate errors in gage readings. Then the rates of drop at various pressures were plotted. To determine rate of leakage at any pressure, multiply line volume by drop in pressure per hour and divide the result by 14.41, which will give the cubic feet of gas leakage per hour.

After determining the leakage as shown in the curves in Figs. 4 and 5, one of the compressor units was carefully overhauled to secure good valve and packing ring conditions. An automatic counter equipped with indicating chart was mounted on the secondary shaft with a pressure spring automatically recording the intake pressure of the compressor cylinders, tracing a line on the same chart. This gave a chart as shown in Fig. 2, in which the outer loops each represent 1000 revolutions. The line was filled and shut in at both ends and allowed to equalize. The compressor was started and the intake pressure held constant by regulating a gate on the station intake. Fifteen-minute readings were taken on all gages and thermometers. The total and intermediate numbers of revolutions of the compressor were taken from a revolution counter. The line pressure being taken at the start and finish of the test, the volume of gas taken from the line would equal the initial pressure minus the final pressure divided by 14.41.

the result multiplied by the line volume. From this the leakage was deducted, leaving the volume of gas taken by the compressor. With the proper temperature corrections, the volume of gas taken by the compressor divided by the cylinder displacement during test, equals volumetric efficiency. Two reliable tests were made, and the average of the two results was taken as the final figure. The results of two such runs were as follows:

	August 4, 1914	August 5, 1914
Time of Start	8 : 35 : 30 a.m.	8 : 52 : 15 a.m.
Time of Stop	12 : 09 p.m.	1 : 10 p.m.
Duration of Test	213½ min.	258 min.
Average Intake Pressure, lb. per sq. in	121.5	122.3
Average Intake Temperature, deg. fahr	81	81
Revolutions during Test	22,445	27,085
Average rev. per min	105	105
Cylinder Displacement per Revolution, cu. ft	13.496	13.496
Cylinder Displacement for Test, cu. ft	2,859,543	3,447,034
Average Line Temperature, deg. fahr	80	79.5
Correct Line Pressure { Start, lb. per sq. in	258.25	289.75
Correct Line Pressure { Stop, lb. per sq. in	127.75	129.50
Drop in Line Pressure during Run, lb. per sq. in	130.50	160.25
Rate of Leakage at Average L.P., lb. per hour	0.98	1.01
Drop of Pressure due to Leakage, lb. per sq. in	3.43	4.34
Drop in Pressure due to Pumping Out, lb. per sq. in.	127.0	155.91
Effective Drop in Atmospheres	8.81	10.82
Volume of Line, cu. ft.	265,742.0	265,742.0
Gas Taken from Line by Compressors, cu. ft	2,344,643.0	2,875,328.0
Corrected to Intake Temperature, cu. ft	2,345,544.0	2,886,829.0
$\frac{\text{Gas from Line}}{\text{Compressor Displacement}}$ = Vol. Efficiency	82.2%	83.7%

Average Volumetric Efficiency = 83.0%

Following this determination gas was drawn through the measuring station, and under test conditions the compressor and meter were operated in tandem for 111 hr. divided into 5 periods. In this test all conditions at Bigheart were practically the same as during the volumetric efficiency test. The Cushing end of the line was opened and the line filled until

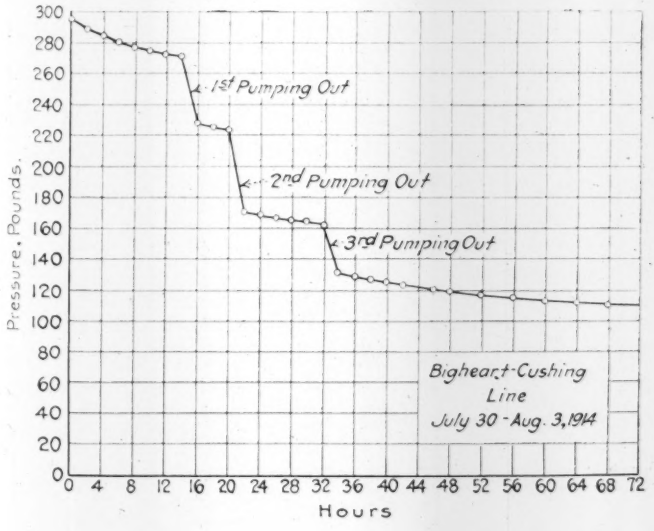

FIG. 4 PRESSURE LOG DURING LEAKAGE TEST

the pressure at Bigheart was above 125 lb. Then the engine was started, and after running conditions were constant the test was started and continued for 5 days. Half-hourly readings were taken at both ends of the line. With the exception of the first period, the results were worked up in twenty-four hour periods. Figures for a typical period are as follows:

THIRD PERIOD OF RUN

4:00 p.m., August 8, to 4:00 p.m., August 9, 1914.
Leakage and Change of Line Pressure during Test:
Bigheart 167 lb. to 178 lb. = 11 lb. increase
Cushing 210 lb. to 218 lb. = 8 lb. increase
Assumed average increase = 10 lb.

Cushing average Pressure 214 lb.
Bigheart average Pressure 173 lb.
41 lb. $41 \times \frac{2}{3} = 27.4$.

173 + 27 = 200 lb., assumed average Line Pressure.
Rate of Leakage at 200 lb. from Test Curve = 0.97 lb. per hour or 23.3 lb. per 24 hours.
Volume of Line = 265,742 cu. ft.

$\frac{10 + 23.3}{14.41} \times 265{,}742 = 613{,}000$ cu. ft. metered but not compressed.

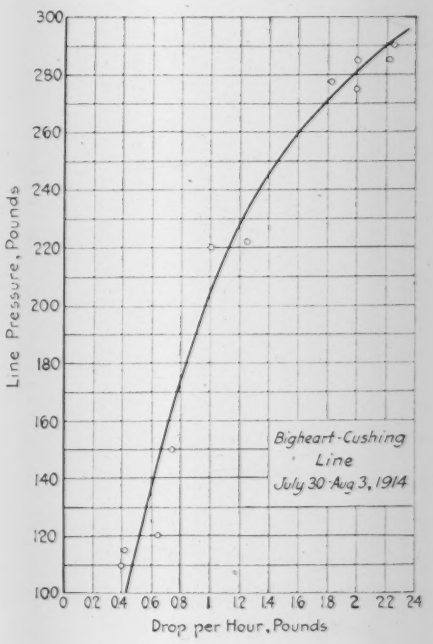

FIG. 5 PRESSURE LOG DURING LEAKAGE TEST

COMPRESSOR CALCULATIONS

Average Intake Pressure, 123 lb. Average Intake Temperature 82° F.
Displacement per Revolution = 13.496 cu. ft.
Revolutions during Test = 151,899. R.P.M. = 105.3.

$151{,}899 \times 13.496 \times \frac{122.5 + 14.41}{14.41} = 19{,}420{,}000$ cu. ft. displaced at 100% Volumetric Efficiency.

Average Volumetric Efficiency from Test = 83%.
19,420,000 × 0.83 = 16,120,000 cu. ft. of Gas pumped at 14.41 lb. and 82° F.
16,120,000
613,000

16,733,000 cu. ft. = amount of Gas accounted for at 14.41 lb. and 82° F.

METER CALCULATIONS

15-Minute Air Coefficient at 14.41 lb. and 60 deg. = 3.146 per M.
Specific Gravity of Gas during Test = 0.714

$\frac{3.146}{\sqrt{(0.714)}} = 3.725$ = 15-Min. Coefficient for Gas at 14.41 lb. and 60° F.

Average Meter Temperature = 82° F.
Sum of Extensions for Test = 2240.551.
2240.551 × 2 = 4481.102, extensions for 15-Min. Coefficient.
3.725 × 4481 = 16,690,000 cu. ft., Quantity that would pass meter with a meter temperature of 60° F.

$16{,}690{,}000 \times \sqrt{(520/542)} = 16{,}350{,}000$ cu. ft. of Gas at 14.41 lb. and 60° F. with Meter Temperature of 82° F.

$16{,}350{,}000 \times \frac{542}{520} = 17{,}045{,}000$ cu. ft. at 82° F.

COMPARISON

$$\begin{array}{r} 17{,}045{,}000 \\ 613.000 \\ \hline 16{,}432.000 \end{array}$$

$\frac{16{,}432{,}000}{19{,}440{,}000} = 84.6\%$, Volumetric Efficiency of Compressor as shown by Meter.

$\frac{17{,}045{,}000}{16{,}733{,}000} = 101.8\%$

The object of this test is to account for the gas metered by the Cushing meter through orifice No. 10,652, using the meter coefficient determined by the Joplin experiments and the recording pressure and differential gages that are in use at the Cushing station. The factors entering into the comparison, for a certain interval of time, are: quantity of gas metered; quantity lost by leakage; quantity put into or taken out of line by change in line pressure; and quantity taken from line by compressors.

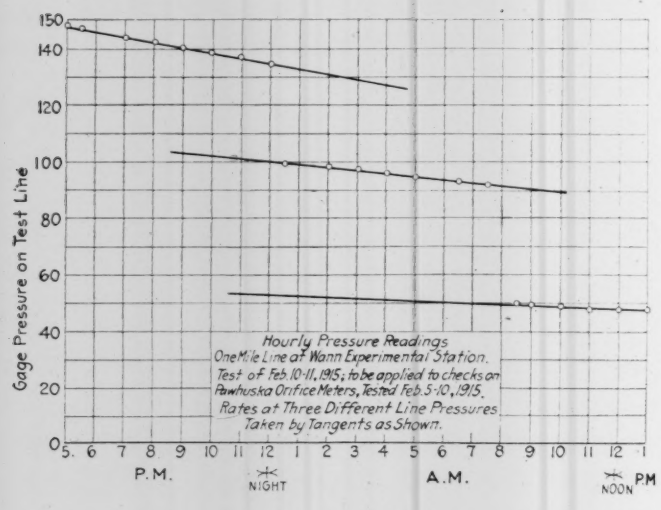

FIG. 6 HOURLY PRESSURE READINGS IN WANN TESTS

$$\text{Quantity of gas metered} = \begin{cases} \text{Gas lost by leakage} \\ \text{Gas added to or taken from line by change of pressure} \\ \text{Gas compressed} \end{cases}$$

All gages and thermometers used were calibrated.

The final result of this comparison is illustrated graphically by Fig. 3, in which the net result of a comparison of the compressor station with the orifice meter shows a constant difference of approximately 2 per cent. Following this test a continuous comparison was carried on by checking monthly totals to secure information as to the consistency of this agreement over a long period of time. At other points these monthly checks were carried on by means of the pipe-line flow formula proposed by Thos. R. Weymouth in a paper read before the Society.[1] For instance, during the month of June, 1915, the amount of gas through the Cushing-Bigheart line compared day by day showed a total compressor station displacement of 377,110,000 cu. ft., using the same volumetric efficiency found by the test. The total orifice meter reading for the same period was 382,480,000, an excess of $1\frac{1}{3}$ per cent. A check of another orifice meter measuring gas through a line consisting of 5.59 miles of 8-in. inside diameter and 9.23 miles of 10-in. inside diameter line gave a flow, by Mr. Weymouth's formula for drop in line pressure, of 333,420,000; and the orifice meter gave totals for the same month of 338,900,000 cu. ft., an excess of $1\frac{1}{2}$ per cent. The pressure in the last two comparisons ranged from 200 to 290 lb. Leakage allowances were made in each case on the same basis as referred to and shown in Fig. 5, for one of these lines.

[1] Problems in Natural Gas Engineering, Trans.Am.Soc.M.E., vol. 34, p. 185.

WANN DISPLACEMENT TESTS

The pump-station and line-flow checks gave approximate corroboration in certain specific instances of the value of the coefficient determined at Joplin, but it was admittedly necessary to get a verification covering as wide a range of pressures and differentials as possible. For this purpose we chose a section of line running from Caney, Kan., to a point near Wann, Okla., which was not in use at the time, and was located so that it could be filled with gas at any time up to a pressure of 250 lb. The dimensions of this line were:

1 From Wann-Portland to 12-in. gate, 1 mile west, 1/23/14.

5,236 ft. of 12-in. ($11\frac{1}{2}$ in. I.D.)	$\times 0.7213 =$	3,776.73 cu. ft.
286 ft. of 10-in. I.D.	$\times 0.5476 =$	156.61 cu. ft.
48 ft. of 8-in.	$\times 0.3474 =$	16.67 cu. ft.
Total volume between 12-in. and 8-in. gates		= 3,950.01 cu. ft.

2 From Wann-Portland to 18-in. gate, $3\frac{1}{2}$ miles west.

2,554 ft. of 18-in. ($17\frac{5}{16}$ in. I.D.)	$\times 1.6347 =$	4,175.00 cu. ft.
18,554 ft. of 12-in. ($11\frac{1}{2}$ in. I.D.)	$\times 0.7213 =$	13,383.00 cu. ft.
286 ft. of 10-in.	$\times 0.5476 =$	156.61 cu. ft.
48 ft. of 8-in.	$\times 0.3474 =$	16.67 cu. ft.
Total volume between 18-in. and 8-in. gates		= 17,731.28 cu. ft.

3 From Wann-Portland to 18-in. gate at Caney, Kan., station.

17,776 ft. of 18-in. ($17\frac{5}{16}$ in. I.D.)	$\times 1.6347 =$	29,058.4 cu. ft.
Total of No. 2		= 17,731.28 cu. ft.
Total cu. ft. in line		= 46,789.68 cu. ft.

There were three gates on the line, so located that the latter could be used as a reservoir having a computed volume of either 46,730, 17,670 or 3,950 cu. ft., according to the size of the meter to be tested. Careful leakage tests were run on the various sections of this line. Figs. 6 and 7 show the leakage on the smallest division at different line pressures. In making these leakage tests, care was taken to seal the gates at each end of the section in use and drain the line beyond the gate at each end through an observed opening to prevent unknown leakages in, or out, through the gate valves. This station was connected up as shown in the diagram, Fig. 8, so arranged that gas from this reservoir was allowed to escape through three orifice meter flanges in tandem, one 8-in. and two 10-in. It was then led through a reducing valve manipulated by an operator, and through a section of line about 300 ft. long to a large discharge chamber, Figs. 9 and 10. This chamber consists of an initial space containing a series of conical baffles to break up eddies in the current, and a second chamber of larger dimensions with an additional baffle having at the outlet end a large flange for conveniently changing the outlet plate. These plates had a central orifice through which gas was discharged to the air by a head in the discharge chamber, maintained as near an absolute constant as possible for giving a test run. This head was observed at one-minute intervals by a sensitive inclined draft gage, and a second similar draft gage attached to the same line was near the man who regulated the reducing gate. This manipulation was carefully controlled to maintain this head as nearly uniform as possible.

It was the aim to maintain a uniform rate of flow from start to finish of each run, although with a wide variation in pressure and differential on the orifice meters in series. Temperatures were taken at each succeeding point on the line and corresponding corrections made. This work was continued from June 20 to the end of September, 1914. Nearly 1200 determinations of coefficients were made. For the purpose of showing the factors taken into consideration, a portion of the complete record of a typical day's run on September 27, 1914, is here given. The disks installed in the flanges that day were:

Flange A. Disk 10.503, 5-in. orifice in 10-in. line
Flange B. Disk 10.402, 4-in. orifice in 10-in. line
Flange C. Disk 8.409, 4-in. orifice in 8-in. line

Table 1 gives the observed data for determining the amount of gas escaping from the reservoir in the six successive runs, and the specific gravity of the gas in each instance.

The following is a key to the symbols used as summaries of readings and calculated values, as tabulated in Table 2, in regard to the Wann displacement tests.

Column number	Symbol	DESCRIPTION
1	h	Observed differential drop in in. of water, across meter orifice disk
2	P	Gage reading (P), corrected to calibration
3	P_a	Corrected gage reading, lb. absolute
4	$\sqrt{(hP)}$	Calculated square root of the product of h and P_a
5	R_1	Calculated rate flow, expressed in cu. ft. per 15 min., at average line temperature and standard barometric pressure B of 14.41 lb. per sq. in. This value is based on the average rate of displacement and corrected for variations in prover temperature
6	T_p	Observed temperature of gas at prover
7	T_m	Observed temperature of gas at orifice meter
8	R_2	Calculated value of R_1 reduced from average line temperature to observed orifice meter temperature
9	C_m	Calculated 15-min. meter constant, for gas at temperature T_m. Found by dividing R_2 (column 8) by $\sqrt{(hP)}$ (column 4)
10	C_f	Cm corrected to 60 deg. fahr.
11	C_a	Calculated 15-min. meter constant, for air at standard condition of 14.41 lb. per sq. in. absolute, and 60 deg. fahr.

Table 2 gives the actual observations for determining the meter constants. The significant results of this series of observations is column 11 giving the air constant for each of the disks tested.

A study of the results of this work led to the belief that assumptions 1 and 2, *ante*, were not perfect, and that it would be necessary to provide means for using a variable factor instead of a constant heretofore applied on orifice meters.

Inasmuch as the number of records to be computed in ordinary operation is so great, the considerable clerical labor involved could not be put in the hands of technical men, and it was deemed advisable to devise a slide rule which could be continually used with a variable factor in accordance with the pressure and differential shown at different points on the chart.

Fig. 11, developed in collaboration by Prof. P. F. Walker, is a series of curves showing results of the entire tests segregated as to differential and pressure, with a view to the determination of the available factor to be used if a variable coefficient should become necessary.

QUESTION OF AN IMPERFECT GAS

Assumption 3, *ante*, that the coefficient determined for air would apply for gas, and assumption 2, in part, that coefficient determined at low pressure would apply for high static pressure, were called in question in a paper read by Prof. P. F. Walker before the Society.[1] It was therefore deemed necessary to pursue the work suggested by him at that time to a conclusion, which could be used as a basis of calculation. In consultation with Professor Walker it was decided to inaugurate simultaneously analogous experiments in the University of Kansas laboratory and at the Wichita Natural Gas Company's laboratory in Bartlesville. Independently and simultaneously, S. S. Wyer, of Columbus, and Robert F. Earhart, working in the laboratories of the Ohio State University, were conducting similar experiments. Up to the present time the findings in these three series of tests are somewhat diverse and not yet ready to submit. The final conclusion of this re-

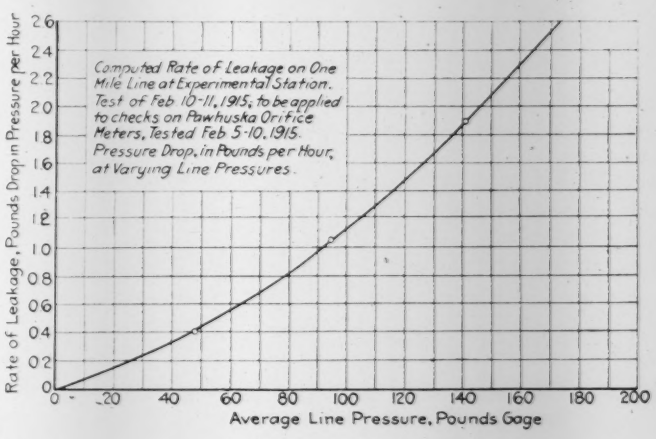

FIG. 7 COMPUTED RATE OF LEAKAGE IN WANN TESTS

TABLE 1 READINGS AND RESULTS OF DISPLACEMENT CHECKS

Small and Large Provers in Tandem with Three Meter Orifices (Nos. 10.503, 10,402 and 8.409)
September 27th, 1914. 12-in. Gate, one mile west of station, shut.
Computed Volume, 3,950 cu. ft.
(Barometer, 29.60 In. Hg. Specific Gravity of Gas, 0.696)

No. or Size of Prover Orifice	Time, Start and Finish	Duration of Test, Min.-Sec.	Corr. Line Pressures, Start and Fin.	Quantity in Cu. Ft. at Line Temperature				Temperature of Line	Avg. U Tube, In.	Avg. Prover Temp.
				Gross for Entire Test	Leakage for Test	Net for Entire Test	Net for Fifteen Min.			
3605	1:22:00 1:05:35	16-25	218¾ 71	40,490	350	40,140	36,690	70	4.43	72
3005	2:06:00 1:45:55	20-05	225¾ 71¾	42,190	420	41,770	31,200	70	4.17	75
2705	3:42:45 3:10:55	31-50	230¼ 3	62,250	570	61,680	29,060	68	4.19	77
16 in.	4:54:15 4:46:20	7-55	220 30½	51,920	140	51,780	98,170	68	2.74	65
12½ in.	5:36:50 5:23:05	13-45	214¼ 13¼	54,930	230	54,700	59,670	66	2.76	66
12½ in.	6:08:30 5:53:10	15-20	207¾ 13¾	53,160	240	52,920	51,790	65	2.04	63

[1]Physical Laws of Methane Gas, Trans. Am.Soc.M.E., vol. 36, p. 781.

search will be of great importance to the natural gas industry, and will determine finally the necessity for a variable coefficient in orifice and pitot meter determinations.

PROBLEM OF SPECIFIC GRAVITY

A very important factor hitherto unmentioned is that of specific gravity. Below are given gravity determinations in three different fields taken at several months' intervals, and a series of simultaneous gravities in seven different fields:

North Osage Gravities		Cushing Gravities		Lot 51	
Jan., 1914	0.585	May, 1914	0.640	Mar., 1915	0.597
Sept., 1914	0.635	Nov., 1914	0.6995	May, 1915	0.603
Nov., 1914	0.653	March, 1915	0.7505	Oct., 1915	0.627
April, 1915	0.647	Oct., 1915	0.695		

Simultaneous Gravities

Sycamore Field	0.5765	Pawhuska Field	0.630	Chilocco Field	0.6925
Local Iola Field	0.590	Augusta Field	0.666	Sedan Field	0.765
Humboldt Field	0.601				

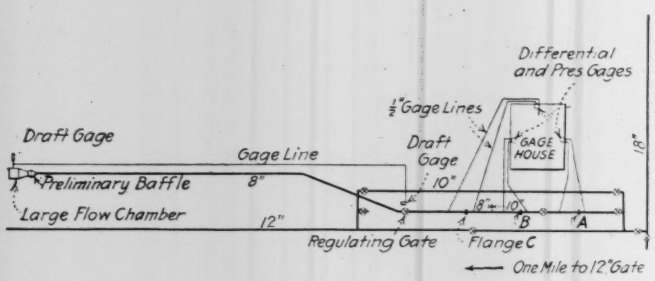

FIG. 8 WANN TESTING STATION CONNECTIONS

In actual practice, gravity determination of gas at a given purchase meter frequently affects a correction in the monthly settlement of from $3000 to $8000, as compared with the gravities taken a month or two previous, or an estimated gravity such as is frequently used. The method of determining this specific gravity with diffusion instruments is rather a delicate manipulation. Even with experienced operators results are liable to vary with the same sample, and it is of great commercial importance to eliminate this uncertainty. It was, therefore, considered necessary to develop a type of gravity determining apparatus which would give approximately accurate and consistent results in the hands of inexperienced and unskilled manipulators, and finally, at the suggestion of W. C. Baxter, a method was proposed using apparatus shown in Fig. 12. The principle involved is simple, consisting of an indicating balance with a beam carrying opposed weights of widely different volume. This balance is enclosed in a chamber with observation glasses at the ends. The balance is adjusted to equilibrium with the chamber filled with air. The air is then completely expelled by a flow of gas and the gas pressure increased in the chamber until the balance is again at equilibrium. The specific gravity is determined by the relative absolute pressure of air and gas necessary to secure the same buoyancy, as shown by indicating balance. The apparatus, even in the crude form shown, seems to be quite sensitive enough to improve materially our gravity records and to involve the personal equation to but a slight degree.

NEW TESTS WITH AIR AT ERIE

A subsequent series of calibrations was run in 1915 to supplement the large capacity meters previously developed by the addition of a series of relatively small capacity meters in 6-in. and 4-in. pipe. The reference quantity chosen for this work was a small holder located at the testing plant of the Metric Metal Works, Erie, Pa., which was courteously loaned to the company's technical staff for the purpose. Check tests were also taken with 8-in. and 10-in. pipe-line orifices; in all about 130 determinations were made, covering the orifices tabulated on the next page.

TABLE 2 WANN DISPLACEMENT TESTS, SEPTEMBER 27, 1914

Large Prover in Tandem with Three Meter Orifices. One Mile of 12 in. Line Used
Disk No. 8,409; Flange C

1 h	2 P_r	3 P_a	4 $\sqrt{(hP)}$	5 R_1	6 T_f	7 T_m	8 R_2	9 C_m	10 C_f	11 C_a
12 in. Orifice: B = 29.60 in.; Line Temperature 66°; Average Prover Temperature 66°; Average Flow, 59.670 Cu. Ft.; Gravity of Gas, 0.696										
11.20	197	211.50	48.62	59,440	70	69	59,790	1.229	1.219	1.017
12.05	185	199.50	49.01	59,560	68	69	59,910	1.222	1.212	1.011
12.82	175	189.50	49.25	59,610	67	68	59,850	1.215	1.206	1.006
13.97	162½	177.00	49.70	59,670	66	68	59,910	1.204	1.195	0.997
15.02	147½	162.00	49.30	59,730	65	68	59,970	1.214	1.205	1.005
16.71	132½	147.00	49.53	59,790	64	67	59,910	1.208	1.200	1.001
18.40	119¼	133.75	49.53	59,790	64	67	59,910	1.208	1.200	1.001
20.14	108	122.50	49.65	59,790	64	66	59,790	1.204	1.197	0.998
22.73	96	110.50	50.10	59,790	64	66	59,790	1.193	1.186	0.989
27.72	75¾	90.25	49.97	59,790	64	66	59,790	1.196	1.189	0.992
38.61	51½	66.00	50.42	59,790	64	66	59,790	1.185	1.178	0.982
46.05	41½	56.00	50.73	59,790	64	66	59,790	1.178	1.171	0.976
Small Prover in Tandem with Three Meter Orifices. One Mile of 12 in. Line Used Disk No. 8,409; Flange C										
No. 3605 Orifice; B = 29.60 in.; Line Temperature, 70°; Average Prover Temperature, 72°; Average Flow, 36.690 Cu. Ft.; Gravity of Gas, 0.696										
3.81	207¼	221.75	29.03	36,580	75	74	36,860	1.268	1.252	1.044
4.22	191¼	205.75	29.41	36,620	74	74	36,900	1.252	1.236	1.031
4.47	182¼	196.75	29.61	36,620	74	73	36,830	1.243	1.228	1.024
4.63	176	190.50	29.68	36,650	73	73	36,860	1.242	1.227	1.023
4.95	162	176.50	29.52	36,690	72	72	36,830	1.247	1.233	1.028
5.25	153¼	168.00	29.88	36,690	72	72	36,830	1.241	1.227	1.023
5.74	143¼	158.25	30.11	36,730	71	70	36,730	1.220	1.208	1.008
5.92	136	150.50	29.80	36,760	70	70	36,760	1.232	1.220	1.017
6.34	125¾	140.25	39.80	36,800	69	70	36,800	1.232	1.220	1.017
7.49	108¾	123.25	30.39	36,830	68	70	36,830	1.212	1.200	1.001
8.08	100	114.50	30.39	36,830	68	70	36,830	1.212	1.200	1.001
9.56	82	96.50	30.37	36,870	67	70	36,870	1.214	1.202	1.003

Table 3 gives data for determination of leakage in the holder and lines. This gives a leakage correction factor for these tests. Table 4 gives the dimensions of the holder. Table 5 is a recapitulation of the derivation of the formula used in determining the air constant in this series of tests. Table 6 is a specimen sheet showing a summary of determinations made on various orifices in 6-in. pipe. The following is a key to the tabulation employed in Table 6 on page 689:

KEY TO TABULATION IN TABLE 6

1st Column.	Heading:	Number of Disk	
2nd Column.		Feet Drop of Holder	Each foot drop is equivalent to displacement of 200 cu. ft.
3rd Column.		Time in Sec.	Taken by stop watch.
4th Column.		T_h	Temperature of holder air, deg. fahr.
5th Column.		T_f	Temperature of flowing air, deg. fahr.
6th Column.		H	Differential across disk, inches of water.
7th Column.		P	Absolute pressure, in lb. per sq. in. on inlet side of disk.
8th Column.		C_a	Fifteen-minute air constant for disk.
9th Column.		C_r	Velocity coefficient, per cent.
		P_h =	Holder pressure (lb. per sq. in., absolute).

ORIFICES USED IN ERIE TESTS

No. of Disk	Size of Pipe, In.	Size of Orifice, In.	No. of Disk	Size of Pipe, In.	Size of Orifice, In.
4051	4	0.506	6204	6	2.002
4071	4	0.755	6302	6	3.003
4103	4	0.996	6401	6	4.000
4123	4	1.250	8101	8	1.010
4154	4	1.500	8205	8	2.006
4174	4	1.754	8304	8	3.006
4205	4	1.997	8451	8	4.500
4223	4	2.251	8506	8	5.005
4251	4	2.504	10151	10	1.500
4301	4	3.002	10302	10	3.007
6101	6	1.002	10451	10	4.502
6151	6	1.502	10601	10	5.999

PRESENT STATUS OF COEFFICIENT

All the orifice calibration work, up to and including the Erie tests, has been compiled and reduced to a basis shown in Figs. 13 and 14, showing the velocity coefficient for all sizes of pipe plotted on a basis of the ratio of diameters of orifice to diameters of pipe in Fig. 13, and on a basis of the ratio area

TABLE 3 LEAKAGE TEST, AUGUST 7, 1915

The readings and calculated results given here show Leakage Test made to ascertain rate of leakage from holder, so proper allowance could be made. This test was started about noon on a Saturday and ran until early Monday morning.

Time

Start 11:30 a.m. Aug. 7, 1915.
Finish 7:00 a.m. Aug. 9, 1915.

Readings	Temperature of Holder, Deg. Fahr.	Reading of Tape
Start	70	26.0
Finish	71	25.85

Leakage (without any allowance for change of temperature during test): 0-15 ft. drop in 43½ hr. This is equivalent to 0.0115 cu. ft. per min. Leakage (with temperature corrections made): 0.0130 cu. ft. per min.

of orifice to internal area of pipe opening in Fig. 14. This shows the degree of variation under the conditions of the different tests, and the solid black line is an averaging line on which coefficients for actual use at the present time are based.

It is the belief of the author that this value may be safely applied within the limits of accuracy shown by the curve to any practicable size of pipe line without further question. The number of experiments which are incorporated in it, and the great variety of conditions under which it has been developed, have practically eliminated any personal equation of observational error of any individual test or series of tests.

TABLE 4 CALCULATED VOLUME OF HOLDER, AUGUST 10, 1915

Measured Diameter of Holder Top (Outside).
16′ 0.5″; 16′ 0.1″; 15′ 11.8″; 15′ 11.9″; 15′ 11.7″; 16′ 0.1″; 15′ 11.7″ and 16′ 0.0″

Average	15′ 11.975″
Allowance for thickness of metal, 2 thicknesses of No. 16 gage iron,	0.125″
Inside Diameter,	15′ 11.850″
or	15.988 ft.

Calculated area = 200.76 sq. ft., which means that one foot drop of holder displaces 200.76 cu. ft. The nominal capacity is 200 cu. ft. per ft. drop; the actual capacity is therefore ⅜ of 1 per cent above the theoretical.[1]

Measured Circumference of Holder

Near Top	50′ 3¾″
Near Middle	50′ 4″
Near Bottom	50′ 4½″

[1] This error of ⅜ of 1 per cent in holder capacity is ignored in the calculation of all tests given in this report. It exactly counterbalances an error of ¾ of 1 per cent in stop watch.

When the exact data are available as to the factor which must be applied to Boyle's Law for gases of differing composition, it is now apparent that the observational points slightly

TABLE 5 DERIVATION OF GENERAL FORMULA FOR CALCULATING HOLDER TESTS ON ORIFICE METER DISKS

Subscript "o" means standard conditions of pressure and temperature, i.e., 60 deg. fahr. and 14.41 lb. per sq. in.

Subscript "h" means actual conditions of air or gas in holder. This will vary from day to day, even for the same holder.

Assuming Flow Temperature of 60 deg. fahr.

$$Q_o = C_a\, hP \text{ for air} = \frac{C_a}{6}\, hP \text{ for gas.}$$

At any Other Flow Temperature T_f.

$$Q_o = \frac{C_a}{6}\, hP \frac{520}{T_f} \qquad Q_h \times \frac{520}{T_f} \times \frac{P_h}{14.41} = Q_o$$

$$Q_h \times \frac{520}{T_h} \cdot \frac{P_h}{14.41} = \frac{C_a}{6}\, hP \cdot \frac{520}{Tf}.$$

$$C_a = Q_h \frac{T_f G}{hP} \frac{P_h}{Th} \frac{520}{14.41}.$$

In this general formula derived above, there are substituted special values for reducing quantity and time of test, giving

$$C_a = 284.6 \frac{\text{Tape Difference (in ft.)}}{\text{Number of Sec.}} \frac{P_h}{T_h} \frac{T_f}{hP}$$

off the curve in Figs. 13 and 14 will be brought still closer to agreement, and we shall have then the necessary data to apply intelligently a variable coefficient if it is found desirable. With the slide rule mentioned earlier, it would be no more difficult to make routine meter calculations with a variable than with a constant coefficient.

RECORDING APPARATUS

It was found necessary to develop a differential recording gage to eliminate certain operating difficulties which resulted in loss of record over considerable proportion of the time for most of the meters in service. The difficulties to be eliminated were:

a rupture of spring from overload in spring type gages

b erratic calibration in spring type gages

c retarding of indicating needle by stuffing-box friction in all types.

d loss of mercury through leakage in mercury float type recording gages, resulting in derangement of zero level of mercury and false reading

e loss of mercury through stuffing box, same type gages and same difficulties.

f blowing over of mercury into pipe line with strong flow of gas in same type of gages.

All these difficulties resulted in loss of record from the time any of the enumerated troubles occurred until a trained attendant could again visit the station and restore the gage to normal condition.

A type of mercury float gage was suggested by H. O. Ballard, superintendent of lines for this company, and has been gradually developed step by step to overcome the various difficulties enumerated. This gage (Fig. 15) is so built that when the gas pressure exceeds the range of the gage the mercury level in the concentric manometer leg drops below the opening at *a*, Fig. 15, and a free flow of gas is permitted without violently disturbing the body of mercury, so that when the pressure again drops within the limits of the gage the fluid returns to normal registering position and the operation of

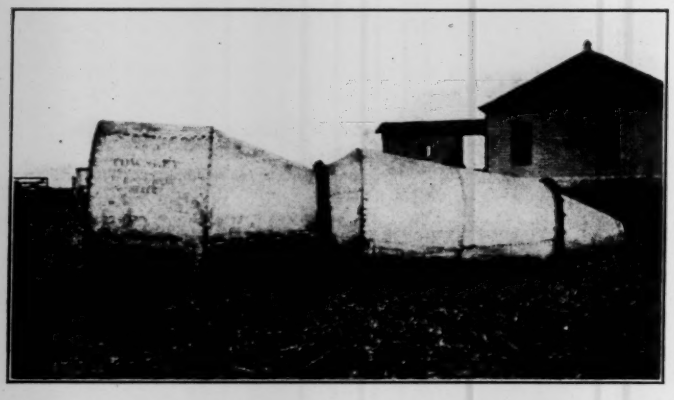

FIG. 9 OUTFLOW CHAMBER WITH SEPARATE ORIFICE PLATES

the gage goes on correctly. The stuffing box is far from the mercury body, and a large chamber above the mercury with a baffle at the top prevents the splash of the mercury through to the outlet pipe. A small automatic check is inserted in the line, close to the gage, which will allow a gentle flow of gas but shut off with any violent current in either direction by the raising of a light ball to the "choke" position. There is also installed a small mercury separating chamber on the high-pressure line to prevent loss of mercury by a back flow.

A convenience for eliminating occasional error caused by using the wrong pressure chart with a given differential record consisted of installing the pressure spring in the same apparatus and concentric with the stuffing box of the differential gage, so arranged that differential and pressure records appear on the same chart, using one color of ink for the pressure and another for the differential. This reduces the number of clocks required and allows the installation to be made with simpler piping.

LIMITATION AS TO RANGE

All large-capacity gas meters have maximum capacity limits which must be made sufficient to take the greatest flow to be measured. The minimum limits are not so definite.

In all the types enumerated the accuracy deteriorates at the minimum limits. In the orifice meter the degree of accuracy is apparent on inspection of the chart, for the reason that the resulting percentage of error occasioned by falsely estimating the position of the differential line becomes a much greater factor in the result as the total differential pressure diminishes. In other words, an error which in a 10- or 12-in.

TABLE 6 SUMMARY OF ERIE TESTS ON 6-IN. ORIFICE METER DISKS

August, 1915

1	2	3	4	5	6	7	8	9	
Date, 8-17-15: Barometer, 29.4 in. P_b = 14.63.									
6302	6	231.0	531	529	4.645	14.57	0.5677	72.8	73.0
6302	6	232.7	531	529	4.56	14.57	0.5692	73.0	
6302	6	253.5	531	529	3.86	14.54	0.5676	72.8	
6204	4	367.9	531	529	5.17	14.59	0.2253	65.0	
6204	3	292.2	531	529	4.37	14.57	0.2313	66.6	
6204	3	317.5	531	529	3.685	14.55	0.2315	66.9	
6204	4	365.5	531	529	5.17	14.59	0.2252	65.0	
6204	3	276.2	531	529	5.115	14.59	0.2255	65.0	
6204	3	290.5	532	531	4.43	14.57	0.2312	66.9	
6204	1	94.7	532	531	4.855	14.58	0.2256	65.3	
6204	1	95.6	532	531	4.61	14.58	0.2294	66.4	
6204	1	94.6	532	531	4.74	14.58	0.2293	66.4	
6401	8	166.1	532	530	3.12	14.52	1.286	92.7	93.0
6401	8	169.7	532	530	2.98	14.51	1.291	93.0	
6401	8	194.3	532	530	2.26	14.49	1.296	93.3	
6401	8	165.6	532	530	3.13	14.52	1.289	92.9	
6151	1.450	239.8	532	531	5.295	14.59	0.1239	63.6	64.0
6151	1.343	240.6	532	531	4.465	14.58	0.1243	63.8	
6151	1.135	240.4	532	531	3.19	14.52	0.1245	63.9	
6151	1.070	240.5	532	531	2.84	14.51	0.1245	63.9	
Date, 8-18-15: Barometer, 29.4 in. P_b = 14.63.									
6101	1	384.2	528	527	5.29	14.60	0.05345	61.6	61.9
6101	1	425.0	528	527	4.35	14.56	0.05331	61.6	
6101	1	470.4	529	528	3.55	14.53	0.05326	61.6	
6101	1	556.9	529	528	2.54	14.48	0.05332	61.6	
6101	1	652.0	529	528	1.815	14.45	0.05397	62.3	
6204	1.7	154.6	530	529	5.19	14.60	0.2278	65.7	
6204	1	94.6	530	529	4.69	14.58	0.2306	66.7	
6204	1	98.6	531	529	4.30	14.57	0.2306	66.7	
6204	1	105.1	531	529	3.715	14.55	0.2325	67.4	
6204	1	111.7	531	530	3.28	14.54	0.2330	67.5	
6204	1	121.6	531	530	2.765	14.52	0.2334	67.6	
6204	1.2	165.7	531	530	2.165	14.51	0.2326	67.4	
Date, 9-2-15: Barometer, 29.6 in. P_b = 14.71.									
6204	6.3	573.0	532	530	5.16	14.71	0.2278	65.7	
6204	3.5	356.0	532	530	4.05	14.67	0.2305	66.7	
6204	2.0	235.0	532	530	2.99	14.60	0.2325	67.4	
6204	1.4	202.4	532	530	1.99	14.58	0.2323	67.3	
6204	1.0	195.8	532	530	1.09	14.55	0.2313	67.0	
6204	1.2	199.7	532	530	1.49	14.56	0.2333	67.7	
6204	1.2	245.5	532	530	1.00	14.55	0.2315	67.1	
6204	1.2	219.6	532	530	1.235	14.56	0.2331	67.6	
6204	1.4	267.4	532	530	1.12	14.55	0.2345	68.0	
6401	7.9	161.4	535	533	3.14	14.63	1.304	93.9	
6401	7.7	158.0	535	533	3.12	14.63	1.301	93.7	
6401	6.8	156.8	535	533	2.505	14.61	1.296	93.3	
6401	6.3	172.0	535	533	1.82	14.59	1.285	92.6	

differential might be negligible, would be an important factor of a 1-in. differential. As a result, with our 50-in. range recorders, we consider the practical limits of capacity to have a ratio of about one to four.

We keep a supply of all size orifices on hand and make frequent changes to keep the gages operating at their most accurate range. Some installations have hour-to-hour variations which run beyond the limits of this ratio, and to avoid

the cost of constant attendance of an operator a convenient apparatus has been devised for automatically changing from one size orifice to another without personal attention. The installation in the pipe line consists of a large revolving plate, pierced by several orifices of different sizes, which may be shifted to come in succession concentric with the pipe. This apparatus is actuated by an automatic shifter deriving its power from the pressure of gas in the line and controlled by a diaphragm operated by trip valves so that the disk will

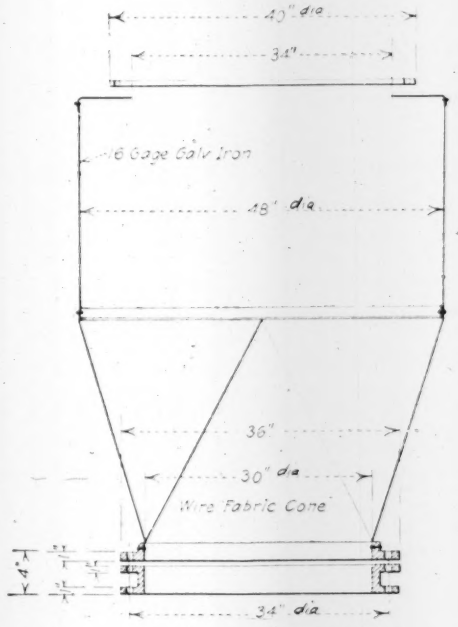

FIG. 10 OUTFLOW CHAMBER WITH SEPARATE ORIFICE PLATES

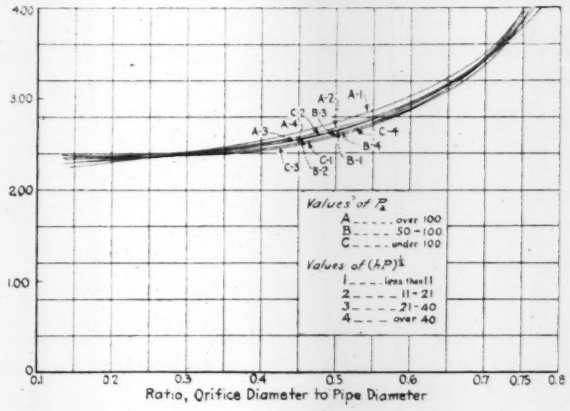

FIG. 11 CURVES ANALYZING WANN COEFFICIENTS

be shifted to the next larger orifice when the maximum differential reaches a predetermined value, say 40-in., and will be shifted to the next smaller orifice when the differential reaches a minimum predetermined value, say 4 or 5 in. This shift makes a sudden and unmistakable jump in the chart, which is readily interpreted. Whether or not it will be necessary to use a third pen on the chart which will trace a line indicating which orifice is in service, will be determined by actual operation.

PULSATION OF FLOW

One problem at present unsolved is obtaining correct measurement with a pulsating flow. This is particularly true where the pulsations are rhythmic, as in the vicinity of compressor stations with reciprocating compressor pistons. An orifice meter early installed at such location failed to check with the station or with meters some 17 miles away on the same line. In endeavoring to locate the difficulty a series of recording gages was installed, both with and without devices for damping out the pulsations in the lines leading to the gages. There were finally connected in parallel a spring recording gage, a mercury float gage of the type originally installed, a Ballard recording gage as described above, and a water U tube. These gages were all calibrated in unison, and agreed very well under condition of steady flow. When the compressor station was started the gages took widely varying positions; some dropped

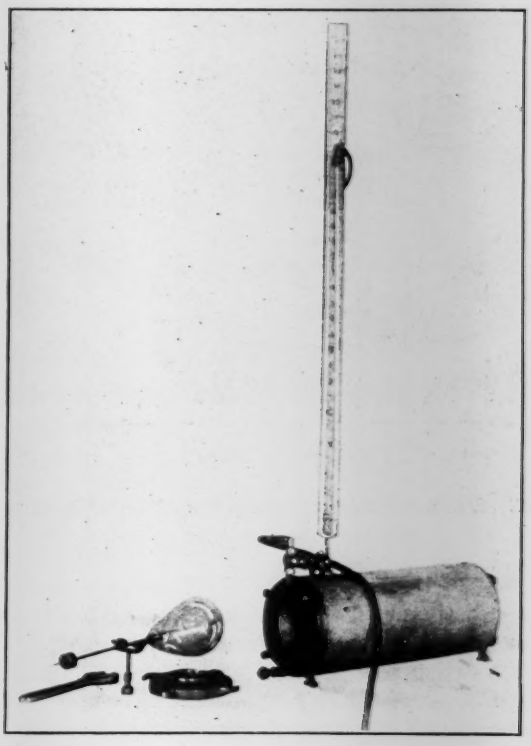

FIG. 12 BAXTER GRAVITY APPARATUS

down to half their former reading despite the increased flow, one took a negative reading as though the flow were reversed and the water column took a wholly indeterminate condition of churned foam; some of the gages moved about in an erratic way and others gave steady indications, but wholly unrelated to the quantity of gas. A proportional meter installed in tandem at this point gave over a period of months a record erratic and irreconcilable as compared with pump station displacement, line-flow formula or meters 17 miles away operating on the same gas with steady flow.

Similar disturbances in the accuracy of the record are occasioned by irregular pulsations resulting from the action of fluid in the line. Disturbances are particularly serious when occasioned by irregular or imperfect action of automatic pressure regulators in the vicinity of the meter. After many unsuccessful attempts to solve the problem of measuring under these conditions, our efforts are now bent on eliminating pulsa-

tion. One attempt is shown in Fig. 16, where a device was installed ahead of a compressor station with the idea of dividing the gas into about 20 different streams and make each stream traverse a path of different length so that the wave motion from different parts of the cycle would be made to interfere at the point where the gas was again brought to a common line. This was almost successful, and it is believed that by a little further calculation and change of arrangement to secure more perfect interference a measurement at this point may be secured.

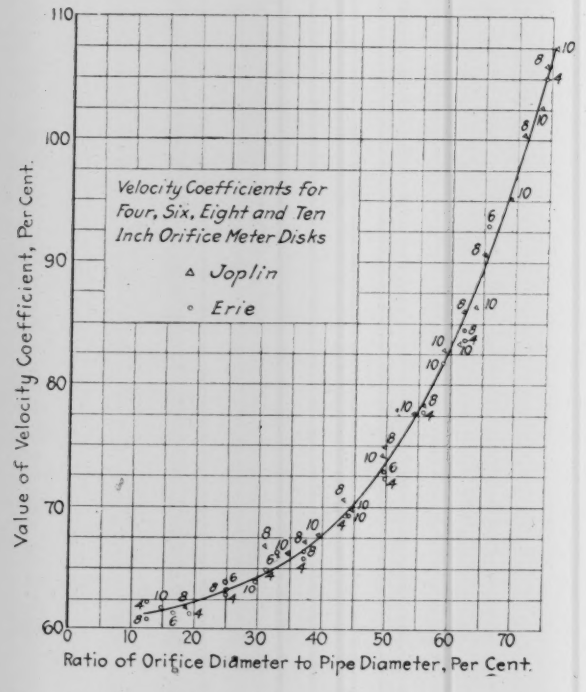
Velocity Coefficients for Four, Six, Eight and Ten Inch Orifice Meter Disks
Joplin
Erie
Value of Velocity Coefficient, Per Cent.
Ratio of Orifice Diameter to Pipe Diameter, Per Cent.

FIG. 13 VELOCITY COEFFICIENTS FOR ORIFICE METER DISKS BASED ON RATIO OF DIAMETER

Pulsations due to fluid and imperfect regulators are obviously questions of simple correction, by separators, drips and mechanical repairs.

CONCLUSION

In conclusion the writer wishes to acknowledge the loyal, able and enthusiastic service of the technical staff entrusted with carrying out these experiments, particularly Mr. E. O. Hickstein, Jun.Am.Soc.M.E.

Much of the apparatus referred to has been suggested by members of this staff, as follows: *a* Fundamental concentric U tube recording gage, Mr. H. O. Ballard; *b* Gravity apparatus and safety device for recording differential gage, Mr. W. C. Baxter; *c* Automatic orifice shift, Mr. J. P. Fisher, Mem. Am.Soc.M.E.

Many incidental developments and improvements should be attributed to others who took important part in the work. Acknowledgment is especially due to Prof. P. F. Walker, Mem. Am.Soc.M.E., for very hearty and enthusiastic coöperation in reviewing data and visiting and inspecting experimental conditions. Further acknowledgment is also due to the many excellent papers that have appeared on measurement of natural gas referred to at various points through the paper.

Particular acknowledgment is due to Mr. Alfred J. Diescher, who has supported the work of arriving at a more sound basis of measurement. This support has not only consisted in generously approving the considerable cost of the work but also in taking an enlightened and detailed interest in the progress throughout, and adopting a broad policy that the truth in regard to measurement, whether favorable or unfavorable from a financial standpoint, should be adopted without coercion or pressure.

DISCUSSION

MR. WELCH CALLS ATTENTION TO NECESSITY OF STANDARDIZING COEFFICIENTS

W. M. WELCH (written).[1] There is one feature in connection with this paper which I would like to call to the attention of the Society, and that is the necessity of standardizing the coefficients to be used in the measurement of natural gas. In the natural gas fields there is a wide divergence in the constants or coefficients used. At the present time, engineers throughout the country are working independently on these problems, such as Weymouth and Cooper in Pennsylvania and West Virginia, Wyer and Biddison in Ohio; Fisher in Oklahoma, Paine and Moeller in California, and numerous others. All of these men are connected in some way with producing or

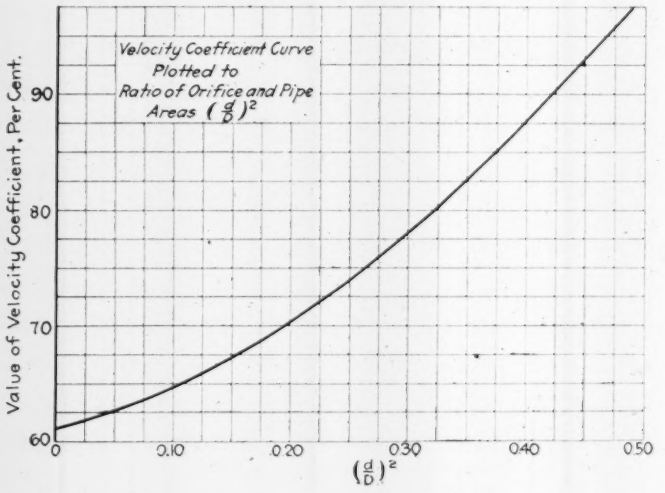
Velocity Coefficient Curve Plotted to Ratio of Orifice and Pipe Areas $(\frac{d}{D})^2$
Value of Velocity Coefficient, Per Cent.
$(\frac{d}{D})^2$

FIG. 14 VELOCITY COEFFICIENTS FOR ORIFICE METER DISKS BASED ON RATIO OF AREA

distributing companies, either as regularly employed or consulting engineers. In addition to these, the Bureau of Standards in Washington is conducting experiments, and the Bureau of Mines, under Burrell, in Pittsburgh is also conducting experiments on Boyle's Law and general work in connection with the measurement and gravity of gases. Also, the state universities of Ohio, Kansas, Wisconsin and elsewhere are working in connection with these subjects. The work being done by these various investigators leads to the use of different coefficients, and where a money consideration resulting from the purchase or sale of gas is dependent upon the coefficient, the matter becomes very important from a commercial standpoint, and much confusion and possible litigation may result from the unsettled condition and uncertainty. It would seem that some effort should be made by some body such as this

[1] 506 Custom House, San Francisco, Cal.

Society, working in conjunction with the Bureau of Mines, the Bureau of Standards, the state universities and others, to correlate the work and establish uniformity in the constants or coefficients, in the types of apparatus to be used in the determination of specific gravity and measurement of gases, and in differential pressure-recording instruments. It is to be hoped that Mr. Fisher's paper will produce some tangible results along these lines.

MR. HILL DISCUSSES PAPER IN LIGHT OF HIS OWN EXPERIENCE

D. M. HILL (written).[1] I am more familiar with the type of orifice meter consisting of a plate 1/8 in. thick with flat edges, and with pressure connections made at the flange 1 in. either side of the plate. The static pressure connection is made from the downstream side of the orifice.

From very careful tests of this type of meter with standardized pitot tubes, it has been established that for differentials up to 100 in. of water the orifice coefficient is constant. I believe, therefore, that the variation of the coefficient with increasing differential, of which Mr. Fisher speaks, is due to the location of the pressure connections at $2\frac{1}{2}$ times the pipe diameter on the inlet and 8 times the pipe diameter on the outlet side of the orifice. By using flange connections a larger differential for a given flow is obtained. This helps somewhat

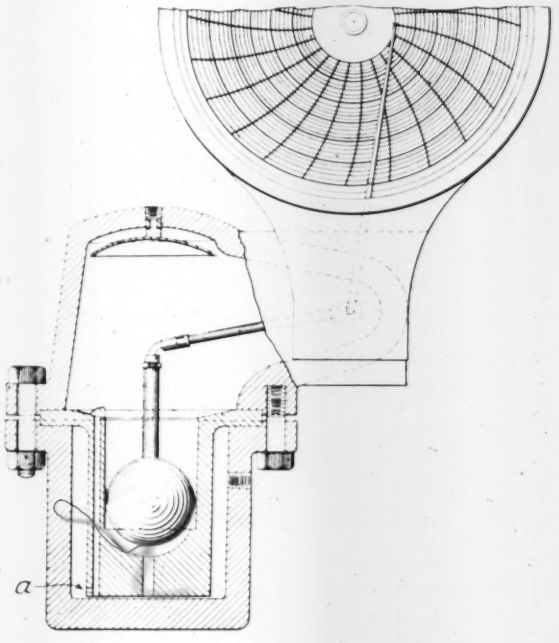

FIG. 15 BALLARD DIFFERENTIAL GAGE

in low flows, where the chances for error are great, due to gage inaccuracies.

I fail to see how the correction to Boyle's Law will bring the observational points closer to the curve in Fig. 13, inasmuch as both the Joplin and Erie tests were performed under the same pressure conditions, and the points are about evenly distributed above and below the curve.

The device which Mr. Fisher has described for automatically changing from one side of the orifice to another without personal attention is most ingenious. I would like a little more information as to how the sticking of the plate against the gasket and the friction against the flange was overcome without permitting serious leakage of gas past the plate. In practice, it has been found that after an orifice plate has been in service for some time, it frequently sticks to the gasket, even with the flange spread apart with jack screws.

[1] Equitable Gas Co., Pittsburgh, Pa.

PROFESSORS GOSS AND WALKER COMPARE ACCURACY OF EARLY AND PRESENT PRACTICE

W. F. M. GOSS. It is evident that our practice in dealing with natural gas is rapidly improving. Fifteen years ago gas companies were not much concerned with errors of one per cent in measuring gas. I recall a pipe line in Indiana which, in the declining days of the gas field in that state, was found to be delivering a million feet of gas per day as shown by consumers' meters, while the compressor displacement in the field, 45 miles away, showed that six million feet of gas were being delivered into the line. The line was reported by the field inspectors to be in good condition.

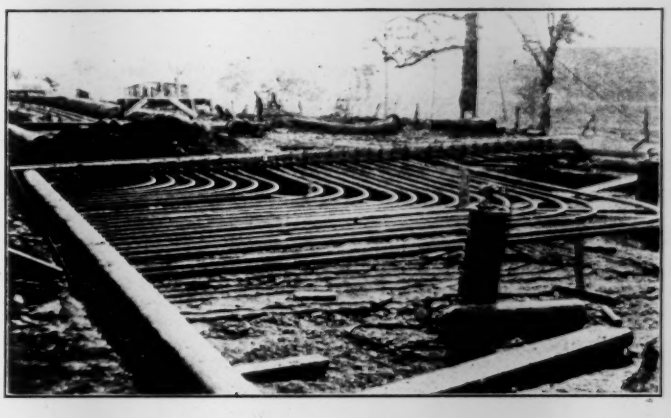

FIG. 16 PULSATION EQUALIZER

Shortage in the supply of gas soon made it necessary to find out what was becoming of the difference between the six million feet going in and one million feet coming out. Measurements taken along the line revealed a steady decline in the quantity of gas passing different sections of the pipe. Differences were accounted for only on the assumption of leakage. The condition of this pipe line was not exceptional, but probably rather typical of practice in the Indiana field during the brief period when cities were supplied through long pipe lines. When the supply of gas was abundant and the amount delivered sufficient for consumption, there was little concern for what leaked out on the way.

All this, it will be noted, is in striking contrast with the attitude displayed by Mr. Fisher's excellent paper.

P. F. WALKER. The conditions in the mid-continental field are not so dissimilar from those which Dean Goss has just cited, except for certain differences in the character of the gas, or, rather, in the character of the substances, mainly vapors and sometimes actual liquids, carried with the gas, and the advancement of the art since the Indiana days. About five years ago I was making investigations of the pipe line conditions for the Kansas Natural Gas Company, the company supplying Kansas City and other towns in Eastern Kansas and Western Missouri. There were three compressor stations on the line, one receiving the gas from the fields, the second, 40 miles away, a step-up station, and the third, 40 miles further, a second step-up station. The piston volume displacement of the sta-

tions fell off, but not, perhaps, more than 8 or 10 per cent each time, the loss, of course, in the main, being due to leaks or to uncharted small users along the lines.

It has been a great pleasure to me to note the attitude and the regard for scientific accuracy displayed by Mr. Fisher's company. When it became necessary to investigate the variation of this gas from the laws of perfect gases, and in spite of the fact that such an investigation seemed almost sure to cause variations disadvantageous to the company, the officials asked us to find out the truth if possible. Two independent sets of investigations as to the variation of this gas from the laws of perfect gases, one by the company and one at the Kansas State University, are now in progress.

The mid-continental gas carries a large amount of matter foreign to gas and gas measurement. At places it is absolutely necessary to take out some of the lighter oils and gasolines in order to avoid danger. A very good grade of gasoline is being manufactured at points along the company's lines. The trouble with the Thomas meter is that its action is based upon the amount of heat required to heat a given

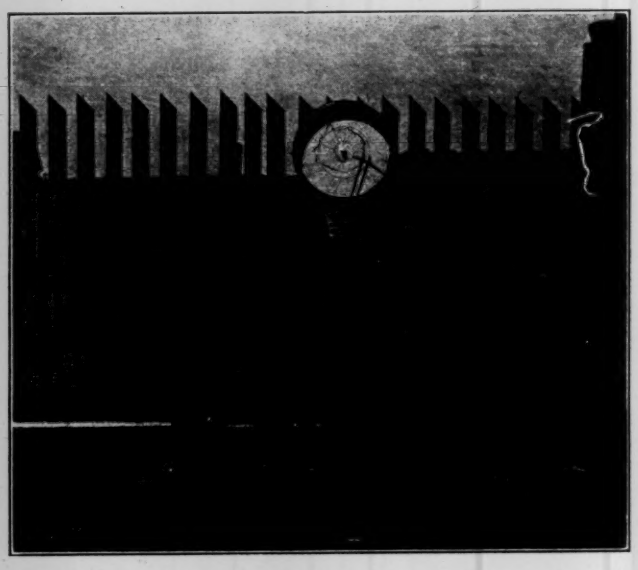

FIG. 17 PRESENT STANDARD SETTING FOR ORIFICE METER

amount of the substance during a given rise in temperature. With the impure gas the specific heat is an extremely variable quantity, and even though the specific heat were known, many of the heavier condensible vapors would probably have been removed before the gas reached its destination, so that the measurement would not be the one required. Moreover, the rock and sand in the gas would destroy so delicate an instrument as the Thomas meter. I do not wish to criticise the Thomas meter, which is a particularly fine instrument, but merely to point out that it is not applicable in this field.

MR. VOORHEES REQUESTS ADDITIONAL INFORMATION

GARDNER T. VOORHEES said that he was particularly interested in the coefficient of flow through orifices because of investigations of his own in refrigeration. He suggested that in addition to the information given in the summary of tests to determine the volumetric efficiency of the compressor, the temperature of discharge at the pressure taken and the diameter and stroke of the compressor be given, as he wished to compare with a formula evolved by him for the volumetric efficiency of ammonia compressors, based on the outlet and inlet temperatures, the results obtained with natural gas.

P. F. WALKER pointed out that the table referred to was a minor element in the investigation, but gave some results which were gratifying in regard to the exactness with which the meter coefficient measured up with the values determined by another test.

THE AUTHOR REPLIES TO POINTS RAISED IN THE DISCUSSION

THE AUTHOR. The instance of which Professor Goss speaks, where six million feet of gas was put into the line to maintain one million feet 45 miles away, was, of course, a very serious case, but by no means unique. Similar conditions have gone on unsuspected in many fields during the early history of the business, for lack of any reliable means of checking gas at the input end.

Mr. Hill refers to a statement (and to Fig. 11) in the original paper as to the variable coefficients at different values of the differential. This statement should perhaps have been modified by the statement that the total variation from a constant of these differentials at the various values was relatively small and has never been taken into consideration as a commercial factor, but merely in some of the theoretical work it was considered that a law might be found governing these slight variations.

In plotting distances of the outlet pressure tap from the orifice flange as abscissae against the differentials as ordinates for various constant rates of flow, it is seen that the recovery of static pressure beyond the orifice with the decrease of velocity, while practically negligible at 1 in. differential, becomes noticeable at higher differentials, and that with the point of observation spaced at 8 diameters there is full recovery and practically a horizontal line on differentials up to and exceeding 50 in., which is the highest used in our work.

In answer to Mr. Hill's further query, no gaskets are used in the orifice-shifting device, but leakage of gas is prevented to an absolutely satisfactory degree of "tightness" by the pressure of accurately ground brass surfaces against accurately ground steel surfaces, the surfaces being kept in contact by springs. The average differential that is used as a maximum, at which the disks are shifted, is about 40 in., at which pressure the leakage through such ground joints is a negligible factor compared with the quantities of gas flowing.

One advantage of using these points of observation ($2\frac{1}{2}$ in. and 8 in.) of the differential is to give orifices which can be used satisfactorily with a wider range between maximum and minimum flow quantities. It also does away with the possibility of the serious effect of violent eddy-currents at the point of expansion beyond the orifice where these changes of energy from dynamic to static pressure are taking place.

I would like to further acknowledge Mr. Hill's criticism of the paragraph dealing with Boyle's Law and Fig. 13, as I find that the points referred to in that paragraph, which were largely observations at Wann at high pressures, have been in some way omitted from the sheet from which the curve was drawn.

Fig. 17 shows what we now consider our standard setting, in which fittings are largely eliminated by the use of oxy-acetylene welding, and the meter is raised out of the ground for convenience in handling and changing disks and eliminating water or fluid from the line adjacent to the meter disks.

DEVIATION OF NATURAL GAS FROM BOYLE'S LAW

By ROBERT F. EARHART,[1] COLUMBUS, OHIO, and SAMUEL S. WYER, COLUMBUS, OHIO

Non-Member Member of the Society

SYNOPSIS OF THE PAPER AND DISCUSSION

THE magnitude of the natural-gas compressing and measuring problem, and known data regarding probable deviation of natural gas from Boyle's law, are summarized in this paper.

Tests were made by the authors in the laboratory of the Department of Physics, Ohio State University, Columbus, Ohio, on eight representative natural-gas samples from various parts of the United States, to ascertain by accurate volumetric measurement whether or not these natural gases did deviate from Boyle's law, and if so, under what conditions. The apparatus used and methods followed are illustrated and described in detail. The data obtained are given in tabulated and graphical form.

These data show:

That all of the observed deviations of natural gas from Boyle's law are in one direction—in favor of the buying company where gas is measured under high-pressure conditions.

That the different gases have marked peculiarities and marked differences of deviation.

That there is no direct relationship between the deviation and ethane content.

That the direct application of Boyle's law to high-pressure natural gas-measuring problems gives only an exceedingly rough approximation.

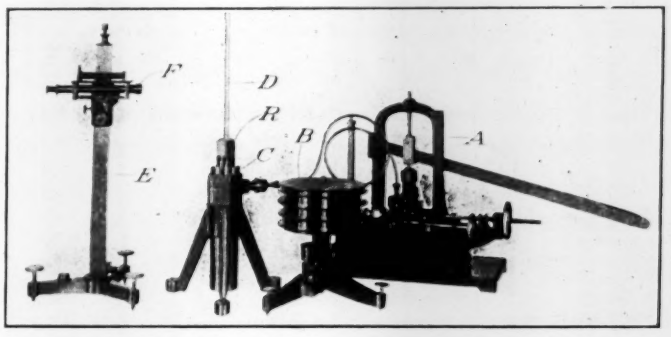

FIG. 1. ASSEMBLY OF APPARATUS

In the discussion, C. N. Cross states that plottings of the authors' observations on logarithmic cross-section paper give values of n (in the equation $PV^n = C$) between 0.92 and unity. Obtaining new initial PV products from the plottings and recomputing, the percentage deviations resulting are in all cases larger than those given by the authors.

E. O. Hickstein suggests a method of testing PV percentage deviation that relies for its accuracy on the correctness of a stop watch, pressure gage and thermometer, and is entirely independent of reservoir volume, prover calibration or the specific gravity of the gas tested.

G. A. Burrell and I. W. Robertson give a formula developed by the U. S. Bureau of Mines, by means of which the deviation from Boyle's law of any natural gas, at any pressure, can be determined from a simple analysis of the gas.

T. R. Weymouth presents a simple empirical equation, by the use of which he states that it is quite possible and practical to obtain measurements of natural gases under high-pressure conditions well within the commercial requirements of accuracy, despite the wide deviation of such gases from Boyle's law.

F. P. Fisher examines in detail some factors of the methods used by different investigators, in order to determine the reasons for disagreement in numerical results obtained in cases where methods differed but slightly.

W. C. Baxter states that in practically all field measurements of gas, large quantities of water vapor and oil vapor are condensed after having passed the meter, causing a shrinkage or loss to the buying company.

P. F. Walker and others who precede him draw attention to the apparent inconsistency of certain results obtained by the authors in the range between 1 and 2 atmos., concerning which the latter state that there was no perceptible deviation from Boyle's law.

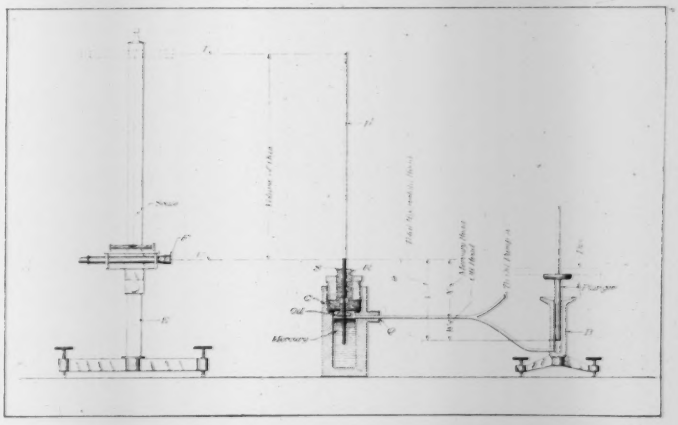

FIG. 2 DIAGRAM OF APPARATUS

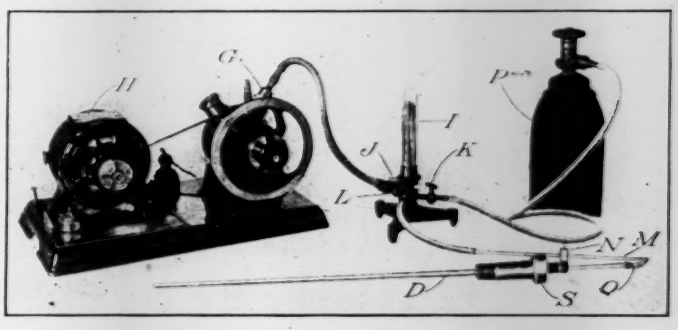

FIG. 3 METHOD OF FILLING CAPILLARY TUBE

THE law that "the volume of a gas at constant temperature varies inversely as its absolute pressure, or that the product of the volume and absolute pressure of a gas is constant," discovered by Boyle in 1660, is the starting point of natural gas compressor and high pressure natural gas measuring calculations. The extent of the commercial application of the law becomes evident when we consider that in the United States over 600,000,000 cu. ft. of gas per annum are now measured under high pressure conditions, and that there are in this country over 200 natural gas compressing stations, aggregating more than 315,000 h.p. of compressor capacity and compressing more than 85 per cent of all the gas used.

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[1] Professor of Physics, Ohio State University.

Presented at the Spring Meeting of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, New Orleans, La., April 1916. Pamphlet copies of complete paper without discussion may be obtained; price 10 cents to members, 20 cents to non-members.

The universal custom in the natural gas business has been to assume that the gas obeys Boyle's law. That the law is not followed rigorously by natural gas, or by any other commercial gas, is evident, however, from the following: Boyle, in his original memoirs in 1661, called attention to the fact that undoubtedly there would be deviations from the law. In the nineteenth century, experiments by Regnault, Amagat and Cailletet showed marked deviations.[1] Professor Walker, in 1912, was probably the first to call attention to the deviation of

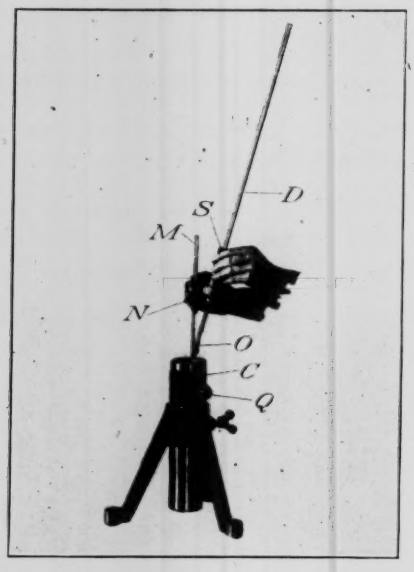

FIG. 4 METHOD OF INSERTING CAPILLARY TUBE SEAL IN MERCURY

permanent gases. The data given in the present paper were obtained by making actual volume measurements of representative natural gases, from atmospheric pressure up to 48 atmos. The tests were made in the Physics Laboratory of the Ohio State University, with the apparatus shown in Figs. 1 and 3. *A*, *B*, *C*, *E* and *I* were made by the Geneva Society.

Referring to Figs. 1 and 2, *A* is an oil pump, *B* a gage tester connected to the oil pump so as to indicate the pressure developed by *A*. *C* is a Cailletet piece (named for the French scientist who designed it) with calibrated capillary glass tube *D*. The inside construction of *C* is shown in Fig. 2. *E* is a cathetometer with moving telescope *F* used for reading the height of the mercury column in *D*.

In Fig. 3, *G* is a Gaede box vacuum pump, driven by the electric motor *H*. *I* is a manometer with cocks *J*, *K*, and *L*, and a small mercury gage underneath the glass, which indicates the degree of vacuum obtained. *M* is a bent glass tube with glass cock *N* and short rubber hose *O*. The hose *O* is tightly wired to *M* to prevent it slipping off. *P* is a standard gas tank used for shipping the gas to the laboratory.

The capillary glass tube *D* had an inside diameter of 3 mm. and was sealed off squarely at the top and held in a vertical position in collar *S* by means of a stuffing box and gland on the inner side of the collar, as shown in Fig. 2. The tube was selected from a large number, and was calibrated in a vertical position by forcing the column of mercury up into the tube and then separating a slug of mercury about 1 in. long from the main column by an air cushion, raising this short slug of mercury through the entire working length of the tube and noting its variations in length by means of the telescope *F* on the cathetometer *E*. The variation in diameter of the tube was so small that volume could safely be considered to be

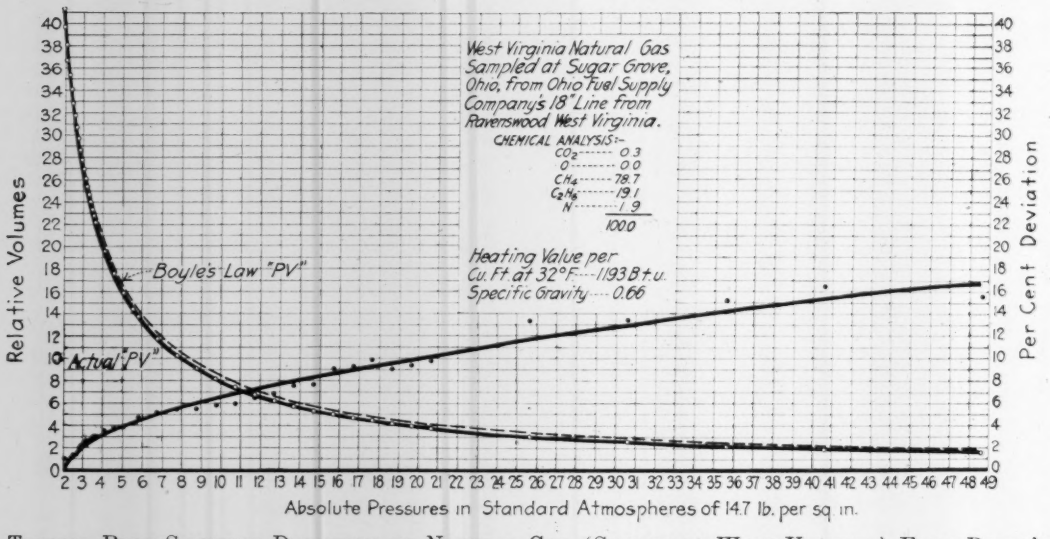
West Virginia Natural Gas Sampled at Sugar Grove, Ohio, from Ohio Fuel Supply Company's 18" Line from Ravenswood West Virginia.
CHEMICAL ANALYSIS:-
CO2 ..... 0.3
O 0.0
CH4 ..... 78.7
C2H6 ..... 19.1
N 1.9
100.0
Heating Value per Cu. Ft. at 32°F. ... 1193 B.t.u.
Specific Gravity ... 0.66
Boyle's Law "PV"
Actual "PV"
Relative Volumes
Per Cent Deviation
Absolute Pressures in Standard Atmospheres of 14.7 lb. per sq. in.

FIG. 5 TYPICAL PLOT SHOWING DEVIATION OF NATURAL GAS (SAMPLE OF WEST VIRGINIA) FROM BOYLE'S LAW

natural gas from Boyle's law on account of the then known deviations of methane gas, the principal constituent of natural gas,[2] and again in 1914, in his paper on the Physical Laws of Methane Gas.[3]

All the data published heretofore referred to the so-called directly proportional to length. The tube *D* was originally surrounded by a water bath, but on account of the practically constant temperature conditions prevailing in the room this was abandoned. The readings for volume contractions were always made with a rising meniscus in *D*.

The order of conducting the tests was as follows: The capillary tube *D* was connected as shown in Fig. 3, with cocks *J*, *L* and *N* open, and *K* closed. By means of *G* the capillary tube *D* was then evacuated and the degree of vacuum noted by the small mercury column in *I*. In operating, the vacuum was

[1] Meyer's Kinetic Theory of Gases, 1877; Preston's Theory of Heat, 1894; Vol. 1, Wüllner's Lehrbuch der Experimental Physik, 1895; Harper's Scientific Memoirs, Laws of Gases, Edited by Carl Barus, 1899.

[2] Proc. Natural Gas Assoc. of America, vol. 4, p. 172.

[3] Trans. Am.Soc.M.E., vol. 36, p. 781.

pulled down to 1 mm. of mercury; cock J was then closed and K opened, allowing D to be filled from the natural gas tank P. This operation was repeated at least four times, to wash out the inside of D thoroughly and leave it free from every trace of air. In the last operation, cock N was closed and M disconnected from the rubber hose leading to L. D and M were then held in a vertical position as shown in Fig. 4, and inserted in the mercury inside of C so that the mercury ran out of the opening Q. When O and the lower end of D were well under the surface of the mercury in C, D was held stationary by the one hand and M pushed down with the other hand, in that way slipping the rubber O from off D underneath the mercury surface in C, thereby entraining the gas in D. The nut R was then screwed down loosely on S, connections made to the oil pump as shown in Fig. 1, and the pump worked slowly so as to force the air out around R. After the air was all driven out, R was then screwed down tightly onto S.

The maximum pressure to be used on B was now applied so as to produce the maximum strain on D, and by means of telescope F and cathetometer E the top position of the inside of D was determined by the line T, as shown in Fig. 2. The pressure in D was now released and the smallest weight that would make the mercury visible in D was applied to B, as indicated by U in Fig. 2. Successive increments of weight on B now produced corresponding contractions in the gas volume D. The gas in D was also allowed to expand, and several readings taken with each gas checked with those taken on compression. The volume changes were accurately observed by means of telescope F and the centimeter scale on cathetometer E.

All readings were made in metric units and pressures reckoned in standard atmospheres of 76 cm. of mercury, or 14.7 lb. per sq. in.

TABLE 1 DEVIATION OF NATURAL GAS FROM BOYLE'S LAW

PENNSYLVANIA "DRY" NATURAL GAS FROM TRI-COUNTY GAS COMPANY, ROYSTONE, PA.

Percentage Analysis { CO_2, 0.1; O, 0.3; CH_4, 77.7 / C_2H_6, 21.7; N, 0.2

Heating Value per Cu. Ft. at 32 deg. fahr. = 1231 B.t.u.
Specific Gravity = 0.66

P Abs. Press. in Standard Atmos.	V Relative Vol. Observed	Boyle's Law Vol.	PV Product of P and V as "Constant"	Per Cent Deviation
2.024	41.62	41.62	84.24	0.00
2.103	39.97	40.06	84.06	0.21
2.183	38.49	38.59	84.02	0.26
2.264	37.04	37.21	83.86	0.45
2.345	35.58	35.92	83.44	0.96
2.429	34.37	34.68	83.48	0.91
2.513	33.18	33.52	83.38	1.03
2.598	32.04	32.42	83.24	1.201
2.684	30.98	31.40	83.15	1.31
2.771	29.98	30.40	83.07	1.408
2.947	28.11	28.62	82.84	1.69
3.124	26.39	26.96	82.44	2.18
3.305	24.93	25.50	82.39	2.24
3.487	23.59	24.16	82.26	2.407
3.671	22.38	22.95	82.16	2.53
4.137	19.79	20.36	81.87	2.89
4.611	17.77	18.27	81.94	2.806
5.088	16.06	16.56	81.71	3.09
5.570	14.65	15.12	81.00	4.00
5.838	13.99	14.43	81.67	3.14
6.822	11.97	12.35	81.66	3.15
7.792	10.42	10.81	81.19	3.75
8.776	9.22	9.60	80.91	4.12
9.764	8.29	8.63	80.94	4.08
10.753	7.48	7.83	80.43	4.73
11.744	6.82	7.17	80.09	5.18
12.737	6.27	6.61	79.86	5.48
13.731	5.80	6.13	79.64	5.78
14.726	5.40	5.72	79.52	5.93
15.721	5.05	5.36	79.39	6.109
20.705	3.82	4.07	79.09	6.51
25.695	3.04	3.28	78.11	7.85
30.688	2.52	2.75	77.33	8.94
35.682	2.12	2.36	75.65	11.35
40.679	1.85	2.07	75.26	11.93
48.675	1.56	1.73	75.93	10.94

Aug. 30, 1915. Barometer 29.4 in. Temperature at start, 67.2 deg. fahr.; at close, 65.0 deg. fahr

TABLE 2 DEVIATION OF NATURAL GAS FROM BOYLE'S LAW

PENNSYLVANIA "WET" NATURAL GAS FROM THE PENNSYLVANIA GAS COMPANY'S "EAST BRANCH" INTAKE

Percentage Analysis { CO_2, 0.0; O, 0.0; CH_4, 61.3; / C_2H_6, 37.7; N, 1.0

Heating Value per Cu. Ft. at 32 deg. fahr. = 1354 B.t.u.
Specific Gravity = 0.75

P Abs. Press. in Standard Atmos.	V Relative Vol. Observed	Boyle's Law Vol.	PV Product of P and V as "Constant"	Per Cent Deviation
1.936	42.03	42.03	81.37	0.00
2.013	40.31	40.42	81.14	0.28
2.092	38.72	38.89	81.00	0.45
2.172	37.21	37.46	80.82	0.68
2.254	35.80	36.10	80.69	0.84
2.336	34.48	34.83	80.55	1.02
2.420	33.26	33.62	80.49	1.09
2.505	32.08	32.48	80.36	1.25
2.590	30.96	31.42	80.19	1.47
2.676	29.92	30.41	80.07	1.62
2.763	28.92	29.45	79.91	1.83
2.940	27.12	27.68	79.73	2.06
3.119	25.52	26.09	79.60	2.22
3.300	24.07	24.66	79.43	2.44
3.482	22.78	23.37	79.32	2.58
3.667	21.60	22.19	79.21	2.73
4.134	19.09	19.68	78.92	3.23
4.607	17.07	17.66	78.64	3.47
5.086	15.42	15.99	78.43	3.75
5.837	13.41	13.94	78.27	3.96
6.811	11.42	11.95	77.78	4.61
7.791	9.91	10.44	77.21	5.39
8.776	8.74	9.27	76.70	6.09
9.764	7.84	8.33	76.55	6.30
10.754	7.06	7.57	75.92	7.18
11.745	6.42	6.81	75.40	7.92
13.732	5.45	5.93	74.83	8.74
15.723	4.72	5.18	74.21	9.65
18.214	4.02	4.47	73.22	11.13
20.706	3.47	3.93	71.85	13.24
25.696	2.70	3.17	69.38	17.28
30.689	2.19	2.65	67.21	21.07
35.685	1.86	2.28	66.37	22.60
40.681	1.57	2.00	63.87	27.40
48.677	1.27	1.67	61.82	31.62

Sept. 2, 1915. Barometer 29.6 in. Temperature at start, 68.0 deg. fahr.; at close, 68.7 deg. fahr.

The plunger on the gage tester was of such diameter that one kilogram of weight was equal to one standard atmosphere of pressure. The plunger itself weighed 0.354 kg. and therefore represented 0.354 atmos. In addition to the disks that belonged to the gage tester B, standard laboratory weights were used for getting the smaller increments of pressure.

The total hydrostatic head indicated by V in Fig. 2 is the sum of a variable represented by mercury column X and a constant represented by the oil column W. The length of this oil column W was kept at 20 cm. in all the tests. The specific gravity of the oil, as determined by a Mohr balance, was found to be 0.866 and therefore equal to 17.32 cm. of water, which in turn was equal to $17.32 \div 76 \times 13.6 = 0.016$ standard atmos.

The readings were classified as follows:

	Typical Values
Barometric pressure in standard atmospheres	0.981
a = Weight on plunger + 0.354	1.176
b = Reading of upper end of gas column in D as T	42.31
c = Reading of lower end of gas column in D as U	1.00
d = Length of gas column = relative volume = $b - c$	41.31
e = Height of mercury in C	−8.00
f = Hydrostatic head of mercury = $X = c + e$.	9.00
g = f in standard atmospheres = $f \div 76$	0.12
W = Hydrostatic head of oil in atmospheres	0.016
V = Total hydrostatic head of oil and mercury = $g + W$	0.136
h = Total net absolute pressure on gas = barometric pressure + a − V	2.021
PV = Product of volume and pressure = $d \times h$	83.50
Deviation in per cent corresponding to various pressures = 100 × "PV" value of lowest pressure divided by "PV" value corresponding to any other pressure, minus 100 = $(100\, P_0V_0/P_xV_x) - 100$.	

TABLE 3 DEVIATION OF NATURAL GAS FROM BOYLE'S LAW

PENNSYLVANIA NATURAL GAS FROM EQUITABLE GAS COMPANY AT TRAFFORD CITY, PRACTICALLY A PURE METHANE GAS

Percentage Analysis: CO_2, 0.0; O, 0.0; CH_4, 98.6; N, 1.4
Heating Value per Cu. Ft. at 32 deg. fahr. = 1050 B.t.u.
Specific Gravity = 0.56

P Abs. Press. in Standard Atmos.	V Relative Vol. Observed	Boyle's Law Vol.	PV Product of P and V as "Constant"	Per Cent Deviation
1.936	42.10	42.10	81.51	0.00
2.013	40.41	40.49	81.35	0.19
2.092	38.79	38.96	81.15	0.44
2.173	37.32	37.51	81.10	0.63
2.253	35.82	36.18	80.70	1.04
2.337	34.57	34.81	80.79	0.89
2.421	33.40	33.66	80.86	0.804
2.505	32.17	32.54	80.59	1.02
2.591	31.06	31.46	80.48	1.28
2.676	30.00	30.46	80.28	1.53
2.764	29.05	29.49	80.29	1.52
2.940	27.20	27.72	79.97	1.92
3.119	25.60	26.13	79.84	2.09
3.300	24.18	24.70	79.79	2.15
3.483	22.87	23.40	79.66	2.32
3.667	21.70	22.23	79.57	2.44
4.134	19.20	19.72	79.37	2.69
4.621	17.20	17.64	79.48	2.56
5.086	15.55	16.02	79.09	3.06
5.838	13.53	13.96	78.99	3.19
6.812	11.57	11.96	78.81	3.42
7.792	10.09	10.46	78.62	3.67
8.777	8.94	9.29	78.47	3.87
9.765	7.99	8.35	78.03	4.46
10.755	7.23	7.58	77.76	4.84
13.236	5.83	6.16	77.17	5.62
15.724	4.88	5.18	76.73	6.23
18.215	4.20	4.47	76.50	6.55
20.708	3.67	3.93	76.00	7.25
25.698	2.90	3.17	74.52	9.38
30.691	2.41	2.66	73.97	10.19
35.687	2.10	2.28	74.94	8.77
40.684	1.82	2.00	74.04	10.09
48.679	1.52	1.67	73.99	10.16

Sept. 2, 1915. Barometer, 29.6 in. Temperature at start, 67.6 deg. fahr.; at close, 67.6 deg. fahr.

TABLE 4 DEVIATION OF NATURAL GAS FROM BOYLE'S LAW

OHIO NATURAL GAS TAKEN FROM THE OHIO FUEL SUPPLY COMPANY'S INTAKE LINES AT SUGAR GROVE, OHIO

Percentage Analysis { CO_2, 0.0; O, 0.0; CH_4, 76.0; C_2H_6, 16.3; N, 7.7

Heating Value per Cu. Ft. at 32 deg. fahr. = 1114 B.t.u.
Specific Gravity = 0.67

P Abs. Press. in Standard Atmos.	V Relative Vol. Observed	Boyle's Law Vol.	PV Product of P and V as "Constant"	Per Cent Deviation
2.022	41.07	41.07	83.04	0.00
2.101	39.42	39.53	82.82	0.27
2.180	37.90	38.09	82.62	0.52
2.261	36.45	36.72	82.41	0.76
2.344	35.10	35.42	82.27	0.93
2.427	33.83	34.21	82.11	1.13
2.511	32.65	33.07	81.98	1.29
2.596	31.52	31.98	81.83	1.49
2.683	30.48	30.95	81.78	1.54
2.769	29.45	29.99	81.55	1.82
2.945	27.60	28.19	81.28	2.16
3.123	25.96	26.59	81.07	2.43
3.304	24.52	25.13	81.01	2.51
3.487	23.20	23.81	80.90	2.64
3.671	22.00	22.62	80.76	2.82
4.138	19.47	20.07	80.57	3.06
4.611	17.43	18.01	80.37	3.32
5.089	15.78	16.32	80.30	3.41
5.840	13.69	14.22	79.95	3.86
6.814	11.70	12.19	79.72	4.16
7.794	10.19	10.65	79.42	4.56
8.779	9.05	9.46	79.45	4.53
9.766	8.07	8.50	78.81	5.36
10.756	7.29	7.72	78.41	5.90
13.237	5.90	6.27	78.10	6.32
15.724	4.90	5.28	77.05	7.77
18.215	4.20	4.56	76.50	8.55
20.708	3.70	4.01	76.62	8.38
25.699	2.96	3.23	76.07	9.16
30.692	2.45	2.71	75.20	10.42
35.687	2.08	2.33	74.23	11.87
40.684	1.84	2.04	74.86	10.93
48.679	1.52	1.71	73.99	12.23

Sept. 3, 1915. Barometer, 29.6 in. Temperature at start, 67.3 deg. fahr.; at close, 66.9 deg. fahr.

The results obtained are shown in part in Tables 1 to 5 and Fig. 5.[1] The paper as presented includes tables dealing with three other gases, one of them being that of Fig. 5. The specific gravities are given with reference to air as unity. The gross heating values given are computed on a basis of 32 deg. fahr. and 76 cm. pressure.

It may be noted that the gases which contain a large percentage of C_2H_6 (wet gases) show larger deviations than the dry gases. The explanation lies in the fact that we are dealing with a physical mixture of gases having two principal constituents, CH_4, methane and C_2H_6, ethane. These have different critical temperatures, one of which lies below, and the other above, the temperature at which our experiments were made.

[1] On account of lack of space, only five tables and one typical plot are here given. The paper as presented contains eight tables and eight charts, the charts being plotted from the tables.

TABLE 5 DEVIATION OF NATURAL GAS FROM BOYLE'S LAW

MIXTURE OF OHIO AND WEST VIRGINIA NATURAL GAS TAKEN FROM THE ST. MARY'S MEASURING STATION OF THE OHIO FUEL SUPPLY COMPANY AT COLUMBUS, OHIO

Percentage Analysis { CO_2, 0.1; O, 0.0; CH_4, 78.1; C_2H_6, 16.8; N, 5.0

Heating Value per Cu. Ft. at 32 deg. fahr. = 1144 B.t.u.
Specific Gravity = 0.66

P Abs. Press. in Standard Atmos.	*V* Relative Vol. Observed	Boyle's Law Vol.	*PV* Product of *P* and *V* as "Constant"	Per Cent Deviation
1.884	38.12	38.12	71.82	0.00
1.963	36.47	36.59	71.59	0.32
2.043	34.95	35.15	71.40	0.59
2.124	33.56	33.81	71.28	0.76
2.207	32.22	32.54	71.11	0.99
2.291	31.01	31.34	71.04	1.07
2.375	29.82	30.24	70.82	1.41
2.461	28.74	29.18	70.73	1.55
2.547	27.72	28.19	70.60	1.58
2.635	26.77	27.25	70.54	1.81
2.723	25.85	26.37	70.39	2.03
2.901	24.21	24.75	70.23	2.105
3.082	22.74	23.30	69.97	2.64
3.265	21.42	21.99	69.96	2.69
3.449	20.24	20.82	69.81	2.88
3.635	19.19	19.75	69.76	2.95
4.106	16.94	17.49	69.56	3.25
4.582	15.11	15.67	69.23	3.74
5.062	13.64	14.18	69.05	4.02
5.546	12.44	12.94	68.99	4.10
5.816	11.85	12.34	68.92	4.21
6.793	10.09	10.57	68.54	4.78
7.776	8.77	9.23	68.30	5.15
8.763	7.77	8.19	68.09	5.48
9.752	6.92	7.36	67.48	6.43
10.743	6.26	6.69	67.25	6.79
12.729	5.22	5.64	66.45	8.08
14.719	4.47	4.88	65.79	9.16
16.712	3.90	4.29	65.18	10.18
18.706	3.45	3.83	64.54	11.28
20.701	3.10	3.47	64.17	12.39
25.693	2.43	2.80	62.43	15.04
30.687	2.02	2.34	61.99	15.86
35.683	1.72	2.01	61.37	17.03
40.680	1.48	1.77	60.21	19.28
48.677	1.22	1.48	59.39	20.93

Aug. 31, 1915. Barometer, 29.6 in. Temperature at start, 66.2 deg. fahr.; at close, 66.9 deg. fahr.

CH_4 has a critical temperature of —140 deg. fahr.; consequently no pressure, however great, could produce liquefaction at the operating temperature, approximately 68 deg. fahr., which prevailed during our experiments. On the other hand, C_2H_6 has a critical temperature of 93 deg. fahr. It follows, therefore, that as the volume of the mixture of gases is diminished, the C_2H_6 constituent approaches the condition of a saturated vapor. When saturation is reached further diminution in volume will produce no change in the pressure exerted by this constituent, but a liquefaction. In case a mixture contains initially a large amount of C_2H_6, this saturated condition will be reached at a lower stage of compression. The fact that further diminution of volume will not thereafter alter the pressure produced by this constituent indicates why a wet gas at high pressures shows such a marked deviation when compared with the pressure-volume product computed for the lower pressures.

Our observations tend to confirm this explanation. There was at no time any visible collection of liquid within the tube, nor could this be expected under the conditions of the experiment. The initial volume of the gas was so small and the surface of the capillary so large, relatively, that we could not expect visible droplets to form.

We noted in the case of wet gases that when a particular stage in compression was reached (peculiar to the gas operated upon) there was a curious unsteadiness and agitation of the mercury meniscus. We observed this carefully in several cases, and found that the range in pressure and volume through which this occurred was very limited. It was probably due to a deposit of liquid taking place on the mercury meniscus, resulting in a change in surface tension. We could confine this region where agitation occurred to variations of pressure of about one-fifth of an atmosphere. Below and above this pressure the meniscus was steady.

We call attention to the bearing of the four preceding paragraphs to gas-handling problems. A gas containing a high percentage of C_2H_6, *i.e.*, a wet gas, will show a very different correction curve than the same gas after having been run through two or three compressors and cooling tanks where presumably the condensate would be removed. On the other hand, dry gases would show small differences before and after compression.

In conclusion, attention is directed to the following facts:

These tests were all made at room temperatures. We believe it would be desirable to have further tests made at higher and lower temperatures.

With the two gases given in Tables 1 and 3, and with another piece of apparatus, we made tests between absolute pressures of 0.978 atmos. and 2.337 atmos. and found no perceptible deviation from the law.

It is important to note that all of the deviations are in one direction, and in favor of the buying company where gas is measured under high-pressure conditions.

The data given herein indicate that the direct application of Boyle's law to high-pressure natural gas measuring problems gives only an exceedingly rough approximation.

The different gases have marked peculiarities and marked differences of deviation. Furthermore, there is no direct relationship between the deviation and the ethane content.

In practice natural gas is handled at high pressures and at a temperature below the critical point of some of its constituents. The failure to recognize this is responsible for many of the serious troubles experienced.

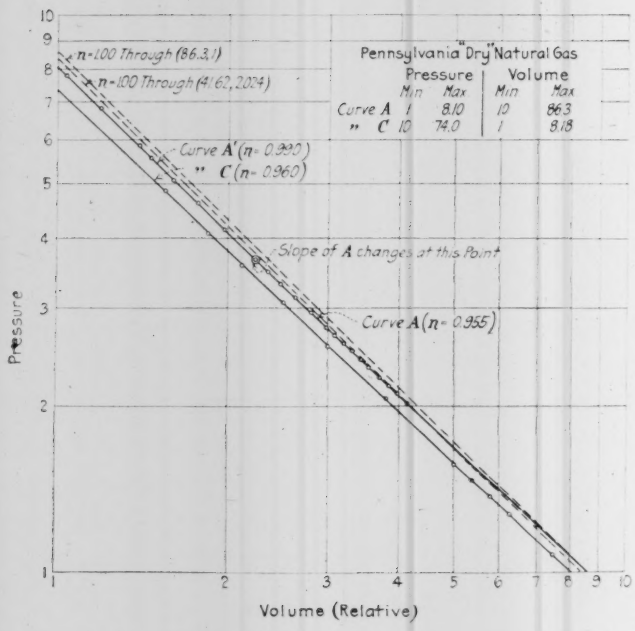

FIG. 6 LOGARITHMIC PLOT OF RESULTS IN TABLE 1

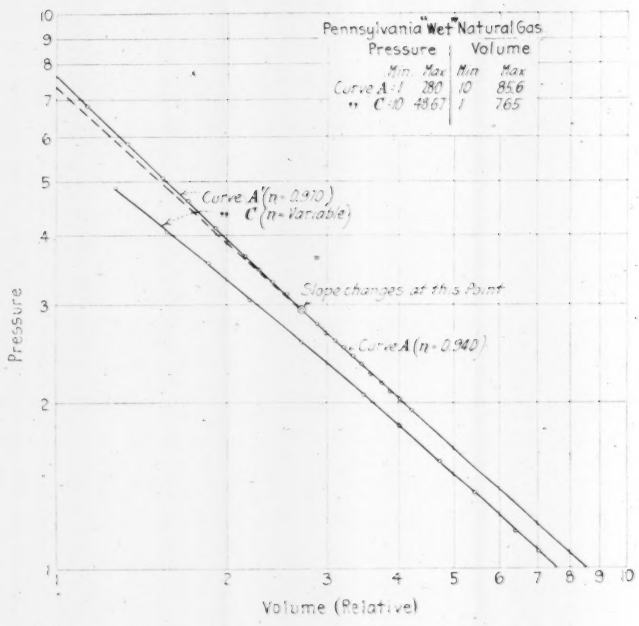

FIG. 7 LOGARITHMIC PLOT OF RESULTS IN TABLE 2

DISCUSSION

MR. CROSS FINDS DEVIATIONS LARGER THAN THOSE GIVEN BY THE AUTHORS

C. N. CROSS (written). In order to study better the relationship between pressure and volume, I have plotted the authors' observations upon logarithmic cross-section paper (Figs. 6-10), where all straight lines can, of course, be expressed by the equation

$$P V^n = c$$

where P = pressures, plotted as ordinates
V = volumes (relative, in this case), plotted as abscissas
c = a constant = the intercept on the P-axis when $V = 1$
n = some number = the tangent of the angle between the curve and the V-axis.

For Boyle's law, n is equal to 1, or the angle of the line and the V-axis is 45 deg.

Limitations of the logarithmic paper used in plotting necessitated three separate lines to include the values covered by the experiments. Each line varies between the following approximate limits. Curve B is omitted because of its short length.

Curve.....	A	B	C
P (atmospheres)....	1 to about 7	About 7 to 10	10 to about 70
V (relative).....	About 80 to 10	10 to about 8	About 8 to 1

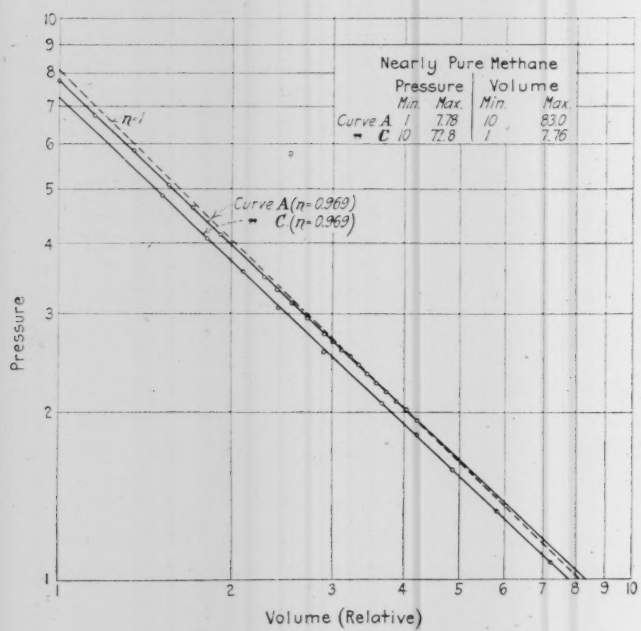

FIG. 8 LOGARITHMIC PLOT OF RESULTS IN TABLE 3

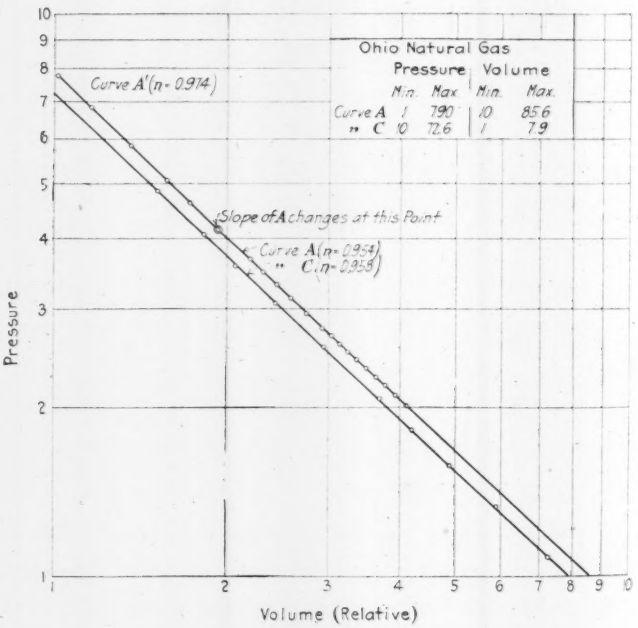

FIG. 9 LOGARITHMIC PLOT OF RESULTS IN TABLE 4

In Table 6 are given the values of n, together with the percentages of ethane and nitrogen in the gases. As was expected, n for each of the eight gases is a number less than unity.

TABLE 6 VALUES OF n

Gas of	Value of n		Per cent of C_2H_6	Per cent of N
	Curve A	Curve C		
Fig. 5.....	0.969	0.942	19.1	1.9
.....	0.975	0.949	18.8	1.2
Table 1...	0.955 and 0.990	0.960	21.7	0.2
Table 2...	0.940 and 0.970	variable	37.7	1.0
Table 3...	0.969	0.969	0.0	1.4
.....	0.980	0.987	9.3	37.7
Table 4...	0.958 and 0.974	0.958	16.3	7.7
Table 5...	0.968	0.923	16.8	5.0

As shown in Table 6, the values of n for curves A differ materially from the values for the corresponding C curves, excepting for gas of Table 3, the practically pure methane

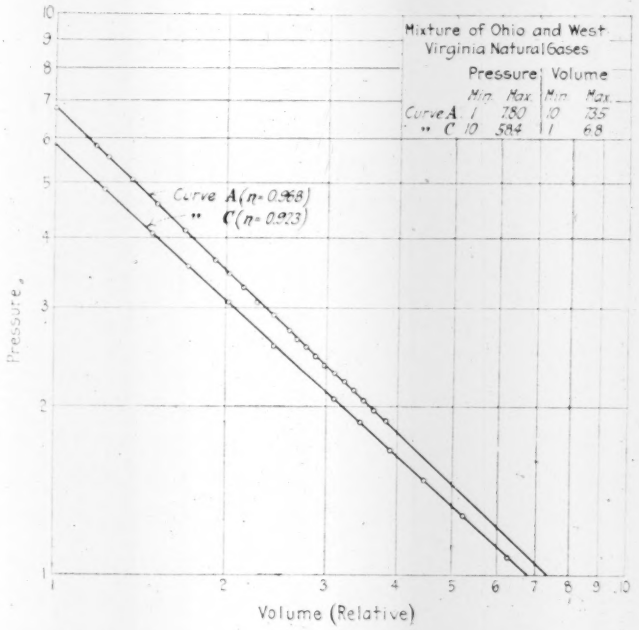

FIG. 10 LOGARITHMIC PLOT OF RESULTS IN TABLE 5

gas. The curves A for gases of Tables 1, 2 and 4, when drawn as two straight lines of different slopes, pass through nearly every point. A slightly curved line drawn through the points, possibly, might represent the facts more correctly. There are not sufficient data to settle this point definitely.

In their conclusion the authors state that no deviation was found for gases of Tables 1 and 3 between pressures of 1 and 2 atmospheres. It is to be regretted that these data were not given, as it would be interesting to plot them upon the logarithmic paper with the others.

If the contract price for gas per cubic foot is based upon a pressure of about 2 atmos., then the percentage deviations as given in the paper are correct. But, as is probably more usual, this pressure is very close to one atmosphere, then the deviation from Boyle's law should be zero at that pressure. Also, in the absence of positive evidence to the contrary and from our general knowledge of the laws of gases, it is hardly to be expected that n would change abruptly at about 2 atmos. to a new value larger than a value between 2 and 8 atmospheres.

I have searched diligently through the literature for experiments upon gases at low pressures, say from 1 to 2 atmos., and have been unable to find any results upon so-called permanent gases giving evidence that n should differ from its value from 2 to 10 atmospheres. Amagat spent considerable time and thought upon gases at very low pressures and was unable to arrive at any conclusion in this matter because of the magnitude of experimental errors, particularly in the measurement of pressures. See *Annales de Chimie et de Physique*, 1883, Série 55, vol. 28, pp. 480-499.

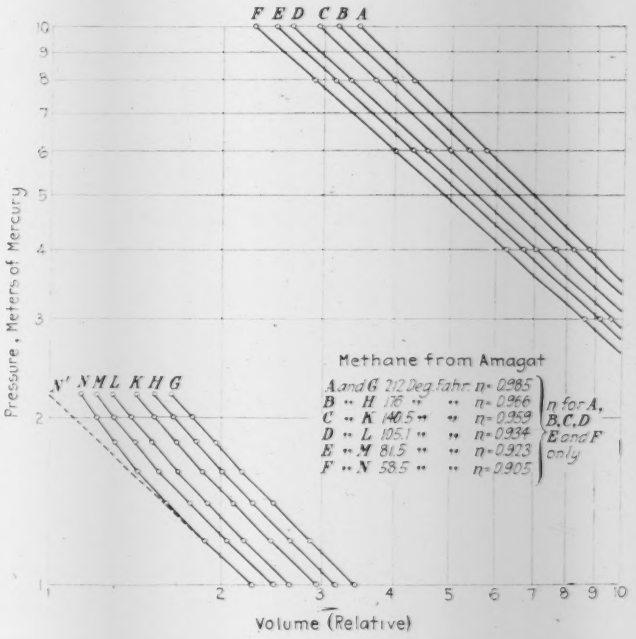
F E D C B A
N' N M L K H G
Methane from Amagat
A and G 212 Deg. Fahr. n=0.985
B " H 176 " " n=0.966
C " K 140.5 " " n=0.959
D " L 105.1 " " n=0.934
E " M 81.5 " " n=0.923
F " N 58.5 " " n=0.905
n for A, B, C, D
E and F only
Pressure, Meters of Mercury
Volume (Relative)

FIG. 11 LOGARITHMIC PLOT OF AMAGAT'S OBSERVATIONS

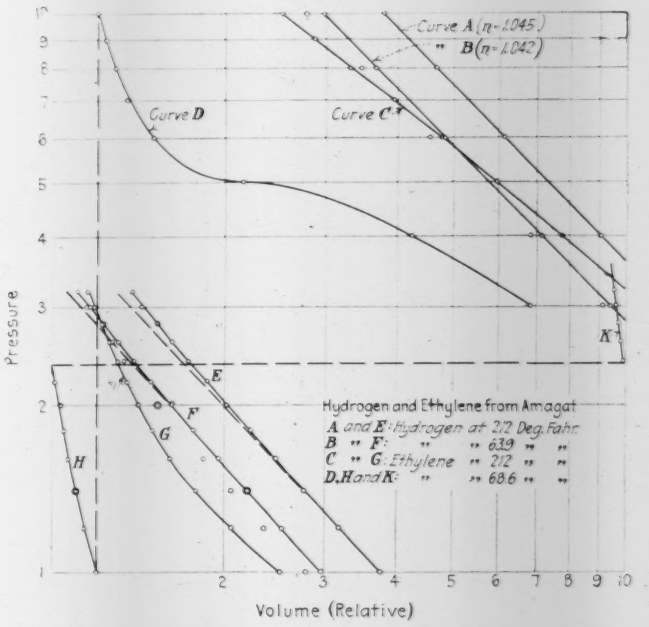
Curve A (n=1.045)
" B (n=1.042)
Curve D
Curve C
Hydrogen and Ethylene from Amagat
A and E: Hydrogen at 212 Deg. Fahr.
B " F: " " 68.9 " "
C " G: Ethylene " 212 " "
D, H and K: " " 68.6 " "
Pressure
Volume (Relative)

FIG. 12 LOGARITHMIC PLOT OF AMAGAT'S OBSERVATIONS

By extending the straight lines on the logarithmic paper back to a pressure of one atmosphere and reading off the volume, a new PV product for the initial, slightly different in every case from that found by the authors at about 2 atmos., was determined, and using this as a starting point, Tables 2, 3 and 5 were abridged and recomputed. The percentage deviation is in every case appreciably larger, *e.g.*, as shown in Table 7, a revision of Table 2. The deviation at 5 to 10 atmos. is increased 40 to 100 per cent. Hence the importance of locating correctly the point of zero deviation is clearly shown.

TABLE 7 (TABLE 2 REVISED)

PENNSYLVANIA "WET" NATURAL GAS

P Absolute Pressure in Standard Atmospheres	V_o Relative Volume Observed	V_b Boyle's Law Volume	Per cent deviation between V_o and V_b	
			New	Earhart & Wyer
1.00	85.6[1]	85.6[1]	0.00[1]	....
1.936	42.03	44.25	5.27	0.00[1]
2.254	35.80	38.01	6.18	0.84
2.676	29.92	32.02	7.02	1.62
3.482	22.78	24.55	7.78	2.58
5.837	13.41	14.70	9.62	3.96
10.754	7.06	7.96	12.72	7.18
20.706	3.47	4.14	19.30	13.24
25.696	2.70	3.33	23.30	17.28
48.677	1.27	1.76	38.60	31.62

[1] From logarithmic curve.

Across Fig. 6 are drawn 45-deg. reference lines through the initial observed point and through the point where the extrapolated curve A cuts the V-axis at a pressure of 1 atmosphere. Hence, at any pressure along curve A, the deviations can be seen at a glance.

Figs. 11 and 12 have been plotted from the observations of E. H. Amagat upon methane, hydrogen and ethylene at high pressures (30 to 420 atmos.), taken from "The Laws of Gases," edited by Carl Barus, 1899. These curves may aid in understanding some of the deviations shown by the natural gas curves. They illustrate briefly the facts as shown by Van der Waals' equation that $(P + a/v^2)(V - b) = C$ for constant temperature, where a/v^2 = the cohesion pressure between the molecules of the gas, and b = the volume of the gas when it is compressed to the utmost.

As a further aid, the following critical temperatures and pressures from the Smithsonian Physical Tables are inserted here.

	H	N	CH_4	C_2H_4	C_2H_6
Critical temperature, deg. fahr.	— 390.5	—220	— 115	48.5	95.0
Critical pressure, atmospheres	20	35	54.9	58	45.2

It is of interest to compare the values of n from Amagat's data for methane with that for the practically pure methane gas in Table 3 of the authors' paper. See Figs. 8 and 11.

	Temperature, Deg. Fahr.	n (from straight portion of curve)
Methane (Amagat)	58.5	0.905
Methane (Amagat)	176.0	0.966
Methane gas (Earhart and Wyer)	67.6	0.968

So great a difference for the value of n would hardly be expected. It has been alleged that the hydrogen used by Amagat was not pure, but contained as much as 20 per cent carbon monoxide. (See "Study of Gases," by M. W. Travers, 1901 ed., p. 165.) Since much more is known about the analysis of gases now than in 1875 to 1885, it is barely possible that the methane experimented upon by Amagat was not pure.

It is shown in Figs. 11 and 12 that gases at temperatures far above the critical temperature plot as straight lines until the pressure becomes very high, when the lines become convex to the V-axis, showing that the value of n increases. For gases below the critical temperature, the curves may be straight for a short distance, but soon become concave to the V-axis. Then, with an increase of pressure, the curvature is reversed and the lines become convex, as is characteristic of the curves of the so-called permanent gases. This explains why the "wet" gas of Table 2 and Fig. 7, containing 37 per cent ethane, is first straight and then concave to the V-axis.

The writer is unable to explain why the slope of the A curves should increase with the pressure in the case of natural gas.

METHOD OF TESTING PV PERCENTAGE DEVIATION IS SUGGESTED BY MR. HICKSTEIN

E. O. HICKSTEIN (written). It would be interesting to know if any precautions were taken in this work to eliminate water vapor present in the gas. If not, is there any probability of the presence of such vapor having an appreciable effect?

Some tests made by the writer about a year ago suggest a method of test which perhaps has not previously been used in this connection. The possible sources of error in this method are so few that the results may be interesting.

In tests made at Wann, Oklahoma, on orifice meter disks, a known volume of pipe line (one mile of 12-in.) was filled with high-pressure gas and closed off from the source of supply. It was then passed through different types of meters at a constant rate of discharge into the atmosphere. The length of time during which gas escaped from the reservoir was taken by stop watch, and from this reading, together with initial and final pressures in the reservoir, and its volume, the rate of discharge could be calculated, assuming that the gas acted in accordance with Boyle's law. The figures presented here were obtained from these tests.

On January 24, 1915, four tests were made without refilling the pipe-line reservoir. The rate of discharge was kept constant, the flow being regulated by an operator who slowly opened a gate through which the gas was expanded to a low pressure and then discharged to the atmosphere through a meter prover. The readings taken during the four runs are reported in Table 8, which is self-explanatory.

From these data was calculated the number of cubic feet of gas at atmospheric pressure passing per minute through a square inch of orifice area, reduced to standard conditions of 60 deg. fahr. flow temperature, 0.675 gravity and 2.70 in. of water pressure in prover. The results appear in column 2 of Table 9.

As the prover was working at all times under identical conditions, it is clear that the discrepancy between these four values must be due to the fact that the calculation of the rate of flow, based on Boyle's law, was incorrect. If, now, it is assumed that Boyle's law is true between 50 and 0 lb. per sq. in. pressure, that is, that the fourth test is correct as fig-

ured, 32.43 is the correct constant for the prover orifice; and the ratio of this figure to the other values in column 2 of Table 9 gives the correction factor for the other tests as recorded in column 3 of the same table.

The excess of gas, over Boyle's law, passing out during each of the first three tests, is expressed in atmospheres and in cubic feet of the gas in columns 4 and 5 of Table 9. The accumulative excess over Boyle's law is shown in columns 6 and 7 of the same table. Fig. 13 indicates how it is possible to correct for the assumption made that the fourth test and Boyle's law give identical discharges from the reservoir, by showing that, in reality, the excess at 50 lb. per sq. in. is 0.010 atmos. (2.74 cu. ft.) over Boyle's law. Correcting for this 0.23 per cent of the theoretical quantity between 47 and 0 lb. per sq. in., the true constant for the prover orifice is 32.50 ($= 1.0023 \times 32.43$). These corrected figures are given in Table 10.

TABLE 8 DATA TAKEN DURING WANN TESTS, JANUARY 24, 1915, TO INVESTIGATE *PV* DEVIATION

(Barometer reading, 29.4 in. Gravity of gas, 0.672).

Run No.	Initial and Final Pressures of Reservoir, Lb. per Sq. In., Gage	Duration of of Tests, Seconds	U-tube Reading of Prover, In. of H_2O	Temperature of Gas at Prover Outlet, Deg. Fahr.	Temperature of Storage Line, Deg. Fahr.
1	200.5 147.0 53.5	1310	2.81	32	35
2	146.5 96.0 50.5	1274	2.81	33	35
3	96.0 47.0 49.0	1239	2.84	33	35
4	47.0 6.75 40.25	1237	2.82	39	35

TABLE 9 PRELIMINARY FIGURES, BASED ON ASSUMPTION THAT BOYLE'S LAW IS TRUE UP TO 50 LB. PER SQ. IN.

Run No.	Calculated Constant for Prover Orifice, Based on Boyle's Law Calculation of Gas Quantity	Ratio of 32.43 (the constant assumed as correct) to Value in Previous Column	Excess Over Boyle's Law for Each Run		Accumulative Excess Over Boyle's Law (Initial Pressure to Zero Pounds)	
			Atmospheres	Cu. Ft.	Atmospheres	Cu. Ft.
1	30.39	1.0672	0.249	68.3	0.412	113.0
2	31.33	1.0352	0.123	33.7	0.163	44.7
3	32.05	1.0119	0.040	11.0	0.040	11.0
4	32.43	1.0000	0.000	0.0	0.000	0.0

The *PV* deviation expressed in per cent is as follows:

At 200.5 lb. per sq. in. (14.9 atmospheres), 2.96 per cent
146.5 lb. per sq. in. (11.2 atmospheres), 1.66 per cent
96.0 lb. per sq. in. (7.7 atmospheres), 0.70 per cent
47.0 lb. per sq. in. (4.2 atmospheres), 0.14 per cent

These percentages will be found plotted in Fig. 14.

While these figures are given more for their interest as a mathematical analysis, the method used appears to possess advantages. It relies for its accuracy on the correctness of a stop watch, pressure gage and thermometer, and is absolutely independent of the reservoir volume, prover calibration, or gravity of the gas.

The gas tested was taken out of a line supplying Oklahoma gas, which was a mixture from the Cushing and Pawhuska fields and had a gravity of 0.672.

It will be noted that the magnitude of the deviation as found in these tests is considerably smaller than any found by the authors and that the shape of the curve is quite different, but as the samples tested by the authors did not come from Oklahoma, this may not be significant.

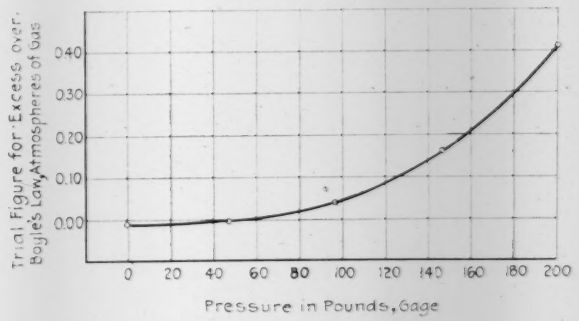

FIG. 13 METHOD OF CORRECTING FOR ASSUMPTION THAT BOYLE'S LAW IS CORRECT BETWEEN 0 AND 50 LB. PER SQ. IN.

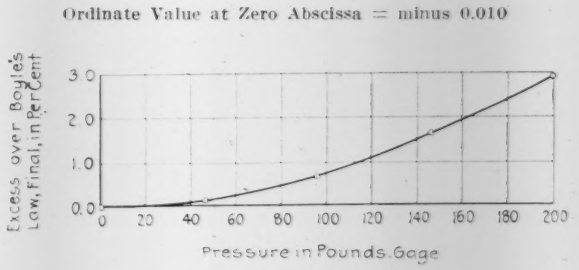
Ordinate Value at Zero Abscissa = minus 0.010
Excess over Boyle's Law, Final, in Per Cent
3.0
2.0
1.0
0.0
0 20 40 60 80 100 120 140 160 180 200
Pressure in Pounds Gage

FIG. 14 FINAL *PV* DISCREPANCY CURVE

TABLE 10 FINAL FIGURES, CORRECTED FOR ORIGINAL ASSUMPTION THAT BOYLE'S LAW IS TRUE UP TO 50 LB. PER SQ. IN.

Run No.	Calculated Constant for Prover Orifice, Based on Boyle's Law Calculation of Gas Quantity	Ratio of 32.50 (the Correct Constant, Calculated from No. 1 Curve, Fig. 13) to Value in Previous Column	Excess Over Boyle's Law for Each Run		Accumulative Excess Over Boyle's Law (Initial Pressure to Zero Pounds)	
			Atmospheres	Cu. Ft.	Atmospheres	Cu. Ft.
1	30.39	1.0695	0.258	70.8	0.443	121.4
2	31.33	1.0375	0.131	35.9	0.185	50.6
3	32.05	1.0142	0.048	13.1	0.054	14.7
4	32.43	1.0023	0.006	1.6	0.006	1.6

MESSRS. BURRELL AND ROBERTSON GIVE U. S. BUREAU OF MINES FORMULA

G. A. BURRELL[1] AND I. W. ROBERTSON[2] (written). The Bureau of Mines have been developing a formula by means of which the deviation of any natural gas, at any pressure, can be determined from a simple analysis of the gas. The advantage lies in the ease with which analyses may be made. See Bulletins 15, 42 and 88 and Technical Paper 109, Bureau of Mines, covering analysis of natural gas and other characteristics.

In order to develop a formula by means of which the compressibility of natural gas (deviation from Boyle's law) could be determined from the analysis, the compressibility of the gases found in natural gas, principally methane, ethane, propane and carbon dioxide, were first determined. The compressibility of nitrogen has been determined by others. This preliminary information is given in the form of curves in Fig. 15. In Fig. 16 is shown the compressibility of the natural gas used in two cities. In Table 11 are the analyses of these two samples, together with seven others.

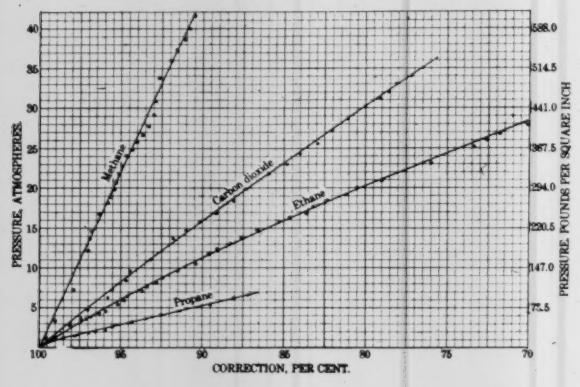

FIG. 15 COMPRESSIBILITY OF GASES FOUND IN NATURAL GAS

TABLE 11 PERCENTAGE ANALYSES OF SAMPLES OF NATURAL GAS FOUND IN NINE CITIES IN THE UNITED STATES

City	CO_2	CH_4	C_2H_6	N_2	Total
Little Rock, Ark.	1.0	96.7	0.0	2.3	100
Bartlesville, Okla.	2.8	89.1	4.2	3.9	100
Cleveland, Ohio.	0.0	83.6	15.7	0.7	100
Los Angeles, Cal.	25.1	59.1	14.5	1.3	100
Palestine, Ill.	0.5	95.6	0.0	3.9	100
Buffalo, N. Y.	0.0	88.1	11.5	0.4	100
Kansas City, Mo.	0.8	84.1	6.7	8.4	100
Charlestown, W. Va.	0.0	76.8	22.5	0.7	100
Olney, Ill. (H_2S = 1.2 %)	0.0	37.5	59.6	1.7	100

The formula was developed as follows: Suppose it is desired to determine the compressibility of the natural gas used in Buffalo at 40 atmos. pressure. Buffalo gas has the following percentage composition: CH_4, 88.1; C_2H_6, 11.5; N_2, 0.4. At 40 atmos. the partial pressure of the

$$CH_4 = 0.881 \times 40 = 35.2 = P_1$$
$$C_2H_6 = 0.115 \times 40 = 4.6 = P_2$$
$$N_2 = 0.004 \times 40 = 0.2 = P_3$$

According to the compressibility curves shown in Fig. 15, the deviations per atmosphere are as follows:

for CH_4, 0.228, $= a$ for C_3H_8, 1.90, $= c$
for C_2H_6, 0.900, $= b$ for CO_2, 0.67, $= d$
for N_2 (not shown), 0.01 $= e$

The total deviation D then becomes

$$D = aP_1 + bP_2 + \text{etc.}$$

The deviation of Buffalo gas at 40 atmos. is then

$$D = (0.228 \times 35.2) + (0.90 \times 4.6)$$
$$= 8.03 + 4.14 = 12.17 \text{ per cent.}$$

The calculated and determined deviations at a pressure of 20 atmos. for different natural gases experimented with by the writers are recorded in Table 12; and the results there given show that it is possible to calculate the compressibility of different natural gases, having given the analysis of the gas.

TABLE 12 CALCULATED AND DETERMINED DEVIATION FROM BOYLE'S LAW OF DIFFERENT NATURAL GASES AT A PRESSURE OF 20 ATMOSPHERES.

	Per Cent Deviation Observed	Calculated		Per Cent Deviation Observed	Calculated
Little Rock	5.8	4.4	Buffalo	6.0	6.1
Bartlesville	4.8	4.8	Kansas City	4.0	4.4
Cleveland	4.3	4.5	Charleston	6.4	7.5
Los Angeles	7.8	7.6	Olney	12.3	12.4
Palestine	4.2	4.4			

MR. WEYMOUTH GIVES SIMPLE AND PRACTICAL METHOD OF MEASURING GAS UNDER HIGH PRESSURE CONDITIONS DESPITE VARIATION

THOMAS R. WEYMOUTH (written). At the suggestion of Mr. Wyer, I made a test of a gas from Roystone Station, where the samples indicated in Tables 1 and 2 were obtained, by a method originally proposed by Mr. E. B. Rosa of the Bureau of Standards. This consisted in filling a small tank of known capacity with the gas at high pressure, which, after its temperature and pressure had been observed, was expanded into a 10-cu.-ft. meter prover. The increase in volume, as indicated by the lift of the prover drum, added to the volume of the

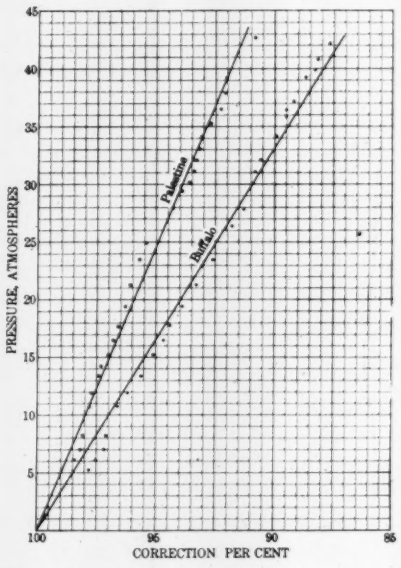

FIG. 16 COMPRESSIBILITY OF NATURAL GAS

[1] In charge, Laboratory of Gas Investigations, Bureau of Mines.
[2] Junior chemist, Bureau of Mines.

original container, gave the total volume of the gas at the pressure and temperature in the prover. In order to maintain the temperature of the gas as nearly constant as possible, it was expanded very slowly, at a rate of about one-half a cubic foot per minute. After the expansion was complete and observations of the lift and pressure of the prover had been made, the connection to the container was broken and the gas was allowed to flow from the prover through the connecting hose with a thermometer in its path, which immediately settled to the value given in the data and remained there. This temperature was the same as that obtained on similar observations of air, made just previous to the run on gas. This, therefore, is considered as giving the true temperature of the expanded gas.

The high pressure of the gas in the tank was measured by means of a sensitive bourdon spring test gage, calibrated against a dead-weight tester at the time of the test. The temperature of the gas in the tank was observed by means of a thermometer placed in contact with the exterior of the tank and heavily lagged. Three observations of pressure and temperature were made after having allowed the container to remain in rooms of different temperatures long enough to become constant in each instance, and from these observations the pressure existing in the tank at the temperature of the expanded gas was computed. The average of the three results was then used in the final computations. The data obtained were as follows:

V = volume of container at 60 deg. fahr. = 0.3938 cu. ft.

B = barometer at time of test = 29.08 in. = 14.249 lb. per sq. in.

Pressure in gas container =

p' = 277.15 lb. per sq. in. gage at 72.5 deg. fahr.

p'' = 270.50 lb. per sq. in. gage at 61.4 deg. fahr.

p''' = 271.00 lb. per sq. in. gage at 62.0 deg. fahr.

or P' = 283.85 lb. per sq. in. absolute at 58.7 deg. fahr.

P'' = 283.85 lb. per sq. in. absolute at 58.7 deg. fahr.

P''' = 283.45 lb. per sq. in. absolute at 58.7 deg. fahr.

Avg. P = 283.53 lb. per sq. in. absolute at 58.7 deg. fahr.

h = pressure in prover through test = 2.07 in. water

P_0 = absolute pressure of expanded gas = $B + 0.036h$ = 14.324 lb. per sq. in.

L = increase in volume = lift of prover = 8.07 cu. ft.

N = actual ratio of total expanded gas volume to the volume of high pressure gas = $(L + V)/V$ = 21.492

N_0 = ratio of volumes according to Boyle's law = P/P_0 = 19.794.

Deviation factor = N/N_0 = 1.0858.

In other words, the percentage error of this gas is 8.58 at a pressure of 283.53 lb. per sq. in. absolute, or 19.29 standard atmospheres. The analysis of the gas showed it to contain 56.0 per cent methane, 36.2 per cent ethane and 7.8 per cent nitrogen.

This method of testing gases to determine their deviation from Boyle's law is extremely simple and rapid, and, I believe, will furnish a ready means for the determination of correction factors to be applied in the commercial measurement of high-pressure gas.

The error introduced by the assumption of the validity of Boyle's law in cases where actual volumes at high pressure are measured by a volumetric meter and reduced to standard conditions by applying direct pressure ratios, is double the error in the measurement by rate-flow meters, such as the pitot tube and orifice, wherein the pressure factor enters under the radical sign.

In order to apply the information given in the paper to actual measurement problems, I have assumed an empirical equation of the form $P^nV = KT$, wherein the characters have the usual significance. Applying in this formula the original observations at about 2 and 20 atmos., the results are shown in Table 13, from which it is seen that the exponent of P is fairly constant, considering the wide variation in the constitution of the gases tested. From this fact I believe that much closer approximations to the true measurement of natural gas can be obtained by the use of the formula given than is now the case with the assumption of Boyle's law.

TABLE 13 COMPUTED VALUES OF n FROM $P^nV=KT$

Gas of	P_1 Obs.	V_1 Obs.	T Obs.	P_2 Obs.	V_2 Obs.	n Computed	Gravity
Fig. 5...	2.029	41.31	534.8	20.706	3.69	1.040	0.66
.....	2.020	41.35	526.2	20.709	3.73	1.033	0.65
Table 1..	2.024	41.62	526.1	20.705	3.82	1.027	0.66
Table 2..	1.936	42.03	528.4	18.214	4.02	1.047	0.75
Table 3..	1.936	42.10	527.6	20.708	3.67	1.030	0.56
.....	2.018	40.98	533.9	20.700	3.75	1.027	0.76
Table 4..	2.022	41.07	527.1	20.708	3.70	1.033	0.67
Table 5..	1.884	38.12	526.6	20.701	3.10	1.047	0.66
T.R.W.	14.320	8.464	518.7	283.530	0.3938	1.028	....
Average.....						1.035	....

In order to determine how closely the empirical formula adheres to the actual expansion curve given by the authors, I have computed from the test of Table 1 the volume corresponding to the observed pressures, using the formula $P^{1.027}V = 85.86$. The deviation of the computed from the actual is less than 1 per cent up to 30 atmos., and by slightly changing the exponent of P and the value of K this deviation can be made much smaller.

It seems, therefore, that in spite of the wide deviation of natural gases from Boyle's law, it is quite possible and practical to obtain correct measurements under high-pressure conditions well within the commercial requirements of accuracy, by means of this comparatively simple empirical relationship, readily determined for any gas by the method described.

In order to employ the equation in the transformation to standard conditions of measurement made by volumetric apparatus, it is merely necessary to multiply the measured volume by the nth power of the absolute pressure ratios.

In the case of measurements with rate-flow meters, such as the orifice or pitot tube, the pressure factor under the radical in the usual formula of such instruments (see Journal Am. Soc.M.E., Dec., 1912, p. 1645) is used with the exponent n, and the numerical coefficient is changed to correspond with the proper value of K in the empirical formula.

In connection with the observed vibration of the mercury column at certain pressures, which the authors explain as due to the liquefaction of the heavy hydrocarbons in the gas, it would be interesting to know if any attempt was made to compute the partial pressures of these heavy gases from the observed pressures and the gas analyses, and note whether or not they were the same for the different samples experimented upon. This should be approximately true in cases where the relative proportions of the various heavy hydrocarbons, reported as ethane, are nearly alike.

MR. FISHER EXAMINES FACTORS OF METHODS USED BY DIFFERENT INVESTIGATORS

F. P. FISHER (written). Because of the disagreement in numerical results obtained from experiments on the deviation of natural gas from Boyle's law when slightly different methods have been used upon similar gases, the writer is led to examine in detail some factors of the methods used which might have led to erroneous conclusions in any or all of the experiments to be quoted.

In the work done in our laboratories, the method used by Mr. Baxter was that of expanding the gas from a metal container of known volume into a second similar container, similar in principle to the cubic-foot bottle, and observing the volume of the expanded gas delivered in order to effect a given reduction in pressure in the original container. This roughly reproduced the conditions under which the gas is expanded in actual industrial application. The experiments were originally attempted by measuring the expanded gas in a precision gasometer of small bore and long travel, but the results were unsatisfactory because of the very difficult element of vapor tension in measuring over water, which showed the necessity of dry measurement.

In the work done at the laboratory of Kansas University at Lawrence, by Prof. Walker and Prof. Garver, a mercury column was used as a source of pressure, and the method of compression was very similar to that in the experiments of Earhart and Wyer, with the exception that the precaution was taken to guard against the presence of water vapor in the gas sample by passing the gas carefully through chloride drying tubes before entering the apparatus. The importance of this was pointed out by our own experience in measuring over water. I do not find reference to any such precaution in the paper under discussion. The pressure in the Kansas University experiments was limited by the available height of the mercury column to slightly over 200 lb., but the apparatus admitted of very accurate work in the very important range between 1 and 2 atmospheres.

Taking specific examples of the results of these three series of experiments at a pressure of about 200 lb. and on similar gases, I find that the relative numerical value of the deviation was approximately 2, 4 and 6 per cent, maintained consistently through a considerable number of samples in each case, and considering the experiments in the order of Baxter, Walker and Wyer. This difference makes necessary first, a careful analysis of the methods to arrive at the possible cause of the difference, and second, corroborative experiments verifying any theories deduced as to the cause of the difference.

I would confine the present discussion to pointing out some possible causes for this difference, which should be validated by various experiments. Our own work has pointed out the great importance of freeing the gas from water vapor in order to get significant results. From this I would assume that the difference between the two compression methods, where similar samples were compressed in carefully calibrated tubes, would lie largely in the fact that the gas was carefully freed from water vapor in one of the tests.

The difference between the expansion and compression methods is more difficult, but a reasonable and possible explanation appears to be pointed out near the close of the authors' paper, where they refer to the probable condensation of a minute volume of invisible fluid under certain specific degrees of compression as practically demonstrated by their observations.

Our knowledge of oils, gasolines and fluids of the paraffin series would tend to show that such liquids will wet glass surfaces freely, whereas glass strongly repels mercury, giving a high and inverted meniscus as compared with gasoline. Any fluid formed would therefore have a strong tendency to wet the glass surface and remain below the upper surface of the mercury as compression was carried to the higher point, giving a false observation as to the true reduced volume by not including all of the substance of the original gas above the mercury. Any fluid thus trapped would represent a relatively large volume of the original gas, so that the slightest tendency in this direction would materially affect the value of the final observations.

It is necessary in filling a good barometer tube to boil the mercury for some time in all parts of the tube to remove the air from the surface of the glass. I would therefore infer that there is considerable probability that in these experiments of compression over mercury, irrespective of the condensation of small quantities of fluid, that a volume of the gas itself is attached to the surface of the glass as the mercury column ascends, giving an unobserved deduction from the true quantity of substance and consequently a false reading of the volume.

In the concluding paragraph Mr. Wyer refers to experiments with a different apparatus in the range between 1 and 2 atmos., in which there was no perceptible change from Boyle's law within those limits. This result seems to be contradictory and irreconcilable with the shape of the curve of per cent deviation in the charts given, which show a maximum divergence of the curve from a horizontal line in the range immediately beyond 2 atmospheres. It would not seem reasonable or consistent with other experiments along the same line that gas should be compressed from absolute pressure of 1 atmos. to 2 1/3 atmos. "with no perceptible deviation from the law" and begin sharply at 2 atmos. to attain the maximum rate of deviation from this same law, for a given increase in pressure, falling off to a minimum deviation at a pressure higher than 4 or 5 atmospheres.

Before accepting as final any of the numerical values so far proposed, more work of a very careful nature should be done upon this subject of divergence from Boyle's law.

COMMERCIAL FACTOR OF DEVIATION POINTED OUT BY MR. BAXTER

W. C. BAXTER[1] (written). The 1912 U. S. report shows 600,000,000,000 cu. ft. of natural gas used in the United States per annum (not 600,000,000).

The authors' statement about the deviation from Boyle's law being in favor of the purchasing company when measured at high pressures is based upon only seven samples of gas tested, and does not necessarily apply to the United States as a whole.

The tests show the expected deviation from Boyle's law without proving it to be a commercial factor and without suggesting a means for correcting for this deviation. The authors point out the impracticability of attempts to correct for the deviation by saying that different gases have marked differences of deviation, and that no relationship can be established, since the exact ethane content cannot be determined, any higher hydrocarbon present being shown as ethane in the usual analysis. Furthermore, any appreciable amount of the higher hydrocarbons would probably have a greater influence than a high percentage of ethane.

Refinements in the measurements of natural gas are to be welcomed by purchaser and selling company, but the statement

[1] Wichita Natural Gas Co., Bartlesville, Okla.

that "the direct application of Boyle's law to high-pressure gas measurements gives an exceedingly rough approximation" is very alarming, if not altogether misleading, since it is made without regard to other considerations that enter into the measurement. The authors, evidently, are not familiar with actual field conditions and the many measurements that are made at high pressure and found to be consistent.

Any sand, oil or water passing through a meter would not be affected by deviations from Boyle's law, but their presence in any considerable quantity results in an overmeasurement. In practically all field measurements, large quantities of water vapor and oil vapor are condensed after having passed the meter, causing a shrinkage or loss to the purchasing company. The difficulty of removing such vapors at or near the fields can be appreciated only by those having actual field experience.

From a commercial standpoint, actual measuring conditions should be considered rather than a single isolated factor.

The remarkable feature of the test results is that the percentage deviation curve has a point of inflection at 2 atmos. pressure, when the tests at lower pressure, not published, show no deviation. This would indicate that the roughest approximation would be made by applying Boyle's law at or near 2 atmos., introducing an uncertainty as to which party is favored. The upper parts of the curves indicate that the percentage factor might become constant or decrease with a sufficiently high pressure. However, very little natural gas is measured above 400 lb. per sq. in. gage, and an extension of the curve would be of no practical value.

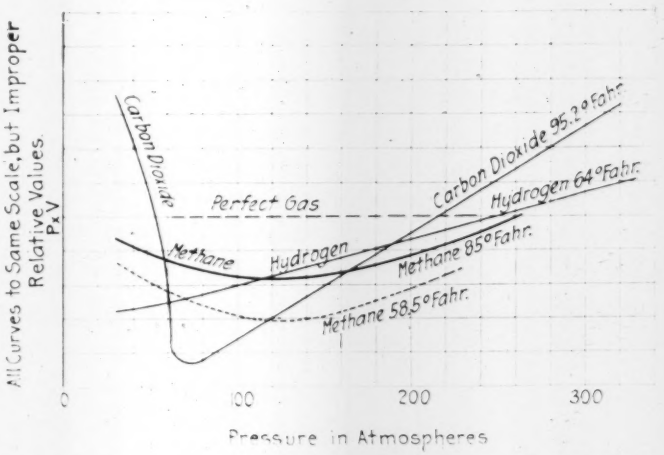

FIG. 17 CHARACTERISTIC VARIATIONS OF GASES FROM BOYLE'S LAW

PROFESSOR WALKER CALLS ATTENTION TO APPARENT INCONSISTENCIES IN THE RESULTS

P. F. WALKER (written). I have taken great interest in the matter treated in this paper, which bears upon the work of several scientists of note, particularly upon that of Amagat.

Amagat set up a mercury column with which to measure pressures in a mine shaft where he could secure high pressures, and for a gas-measuring tube employed a closed tube similar to that employed by the authors. After developing the characteristic curve for hydrogen shown in Fig. 17, he proceeded to investigate several gases not far removed from their critical states at ordinary temperatures, such as carbon dioxide, ethylene, and methane. The form of characteristic curve for the first two is that shown in Fig. 17 and marked carbon dioxide. The critical point, where the gas changes from diminishing to increasing values of the product, PV, is sharply marked. For higher temperatures this is less sharply defined, as represented for methane. At the higher temperatures and pressures the curves all appear to approach the form of that for hydrogen.

On the low-pressure side the gases close to saturation pass promptly from the critical point to a form of curve convex toward the horizontal line indicating the perfect gas, which convexity continues to the lowest pressures. At the lowest pressures the rate at which the gas deviates from the perfect gas with changing pressure becomes small, the curve being asymptotic to the horizontal. As these gaseous vapors become more like true gases this convexity diminishes, it being as though the methane curves of Fig. 17 were continued to the left without reversal of curvature. Whether methane reverses or not has not been shown absolutely as yet, but there is evidence to show that at the lower temperatures the curve does reverse.

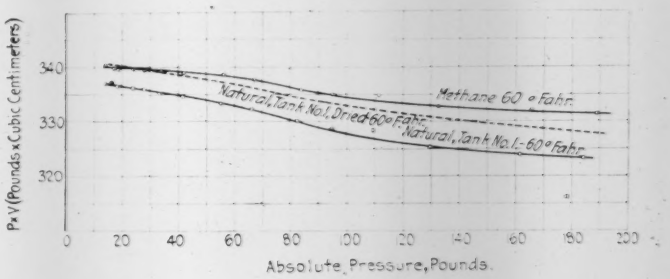

FIG. 18 LOW PRESSURE RESULTS ON METHANE AND NATURAL GAS

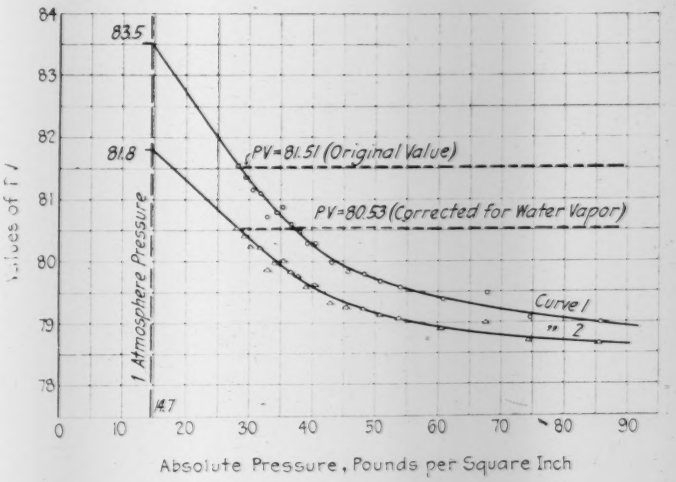

FIG. 19 AUTHORS' VALUES IN TABLE 3 REPLOTTED AND EXTENDED

Fig. 18 shows the definite character of the curve for methane at 60 deg. fahr. for pressures down to atmospheric, as determined with the apparatus in use in the Kansas laboratory. Alongside the methane curve is shown, also, the curve for a sample of natural gas containing about 87 per cent methane drawn from the Kansas-Oklahoma gas field. The effect of drying this gas before its admission to the measuring tube of the apparatus is shown by the broken curve to be but slight. The undried gas indicates a greater total deviation from the

perfect gas, and both indicate greater deviation than does pure methane.

These curves are in sharp contrast to the form of curve given by the data supplied by the authors. Fig. 19 is constructed from the data taken from Table 3 by the authors, it being for the natural gas which contains 98.6 per cent methane, with the remainder nitrogen. If the sharp curvature secured by the authors for all of their gases at the low pressures were due to the presence of condensible vapors, we would expect this curve for almost pure methane to be distinctly different in form. The only difference is in magnitude, however, which really is the result to be expected. The curve on original data in Fig. 19 has been extended to meet the atmospheric pressure line, at a value of PV of about 83.5. If percentages of variation were to be calculated from this value, and in the gas business we want volume referred to atmospheric pressure, they would be considerable greater than those given by the authors.

As to the form of the curves at low pressures, it is clear that the sharp variation is such as would be produced by a constant error in the observed pressures. Such an error, the amount being added to the true pressure, would be of maximum significance at low pressure where the added quantity would be large in proportion to the true value, and would produce an effect on the form of the curve as noted. In order to determine if the presence of water vapor in the gas would account for the peculiarity, I have recalculated the values of PV after deducting from P the partial pressure which would be produced by vapor in the saturated state at the temperature of 67.6 deg. fahr. This partial pressure is 0.337 lb. per sq. in., or 0.023 atmos. The result is shown in Curve 2 of Fig. 19. Clearly this is not enough to change the form vitally, although it acts in that direction.

All of these curves in Figs. 18 and 19 should be viewed as extensions of the curves for methane by Amagat as shown in Fig. 17, the extension being to the left into the region of low pressure. The scales of these drawings differ so greatly that the imagination must assist the eye in taking this view. It would be unnatural to expect so sharp a change in characteristics of the gas at the low pressures as is indicated in the results of the authors, and then after an increase in pressure come to the critical point of change indicated in Amagat's curves by a curvature in the same direction as the first. It is not to be expected that the maximum rate of deviation would come at the lowest pressure unless it is produced by a combination of several vapors in saturated condition. As much as I admire the excellent work which has been done by the authors, I cannot agree with the results here shown as regards the deviation at low pressures. I wish to emphasize again that it is important in the natural-gas industry to obtain the variation in volume between the measurement made at some high pressure and that at a pressure close to one atmosphere. These deviation curves, if extended in accordance with the same general law of curvature, would show from atmospheric pressure conditions a deviation so great as to be out of proportion.

W. F. M. Goss remarked that the paper was an instance of the permanent value of researches going on in our great educational institutions.

GARDNER T. VOORHEES said that he had made an investigation with carbon dioxide and had concluded that "at the critical point, and for some distance above it, the substance might be a chemical mixture in solution in the gas and not a chemical mixture."

According to *The Engineer* (July 28, 1916), it has been found that ordinary cast iron can be readily cut by a carpenter's saw if the iron be heated.

The pitch diameter ($P.D.$) of a V-grooved pulley can be readily determined from the formula: $P.D. = D + (d/\sin \frac{1}{2}a) - (b/\tan \frac{1}{2}a)$, where D = diameter at bottom of groove, d = diameter of belt, and b = width of groove at bottom, all in inches; a = angle between sides of grooves, deg.—C. A. M. Weber, in *The Electric Journal*, August, 1916.

The initial pressures of different explosives when detonated in their own volume are as follows: Straight dynamite (nitroglycerine mixed with an inert base), 80 tons per sq. in.; blasting gelatine, 113 tons; guncotton, 71 tons; black powder, 21 tons. Blasting gelatine, the most powerful, has the highest rate of detonation: 25,262 ft. per sec. as against 22,368 for straight dynamite and 984 for black powder.—*Mining and Scientific Press.*

A machine for cutting the teeth of double helical or herringbone gears, designed and patented by W. F. Sykes, is described in *Engineering*, July 14, 1916. The machine is a development of the principle underlying the well-known Fellows gear shape (Edwin R. Mem.Am.Soc.M.E.), the teeth being formed in the blank by cutters which are themselves gear wheels. Two cutters are employed, one of which cuts the teeth belonging to the left-hand helix, and the other those corresponding to the right-hand helix. The cutters are reciprocated to and fro by cranks, and the teeth thus cut meet in a sharp angle, without the clearance which is necessary in the case of hobbed gears.

In a recent address before the Brooklyn Engineers Club, William J. Baldwin, Mem.Am.Soc.M.E., gave a description of an apparatus designed by him to be placed between the boilers of a power house and the stacks for preventing the discharge from the latter of cinders and dust. Such elimination has been successfully accomplished with the aid of water; numerous installations operating under that method being in use. However, it was stated that too much water cools the gases and impairs the draft, that the corrosive action set up by the water in the presence of flue gases eats away the smoke connections, and that even cement surfaces and chimney linings are injuriously affected.

Mr. Baldwin's method is denominated a dry one, and when operating in that way it has been shown that as nigh as 95 per cent of the dust has been removed, and practically all of it when water is used in addition. An advantage in designing such a method is offered by the fact that, given favorable conditions, there will be a gravity precipitation of the dust from the air.

The dust is centrifugally expelled throughout a complete circle within an annular enclosure and through a perforated flat ring therein, the particles remaining in the box and falling to its lower side for later removal.

When the annular chamber was revolved it was found that an added impulse was acquired by the particles projected against the inner surface and they were thus prevented from returning. For this reason the annular chamber was made revolvable.

Alluding generally to the necessity for eliminating dust and cinders from flue gases, Mr. Baldwin stated that with boilers so frequently being operated at 300 per cent rated capacity, the demand for such removal was more insistent than ever.

EXPERIMENTS ON WATER FLOW THROUGH PIPE ORIFICES

By HORACE JUDD, COLUMBUS, OHIO

Member of the Society

DURING the past ten years papers upon the flow of fluids have appeared from time to time in the Transactions of the Society; most of these have dealt with the flow of air and gas, although a few have treated of the flow of steam. The methods set forth in these papers have for the most part centered around the venturi meter and the pitot tube.

During this period, also, many forms of meters have been brought out for the measurement of air, gas and steam, as well as of water, all more or less successful in operation, and of these, also, a great many have made use of the principles of the venturi meter or the pitot tube.

The pipe orifice, consisting of a diaphragm in which there is an orifice inserted in a pipe, has not hitherto met with much favor for the measurement of the flow of steam or water in a pipe, although it is coming into use for air and gas measurement and has been used with certain types of steam meters of German make and also in Bailey flow meters.

The chief objections to the pipe orifice have seemed to be that a special form of orifice flange was needed and that considerable uncertainty prevailed concerning the pressure conditions adjacent to the orifice, so that the working coefficients for an orifice in a pipe were not so reliable as those of the venturi meter or the pitot tube.

About two years ago, while employing the Bailey meter to measure the steam used by an engine, the writer became interested in the orifice as a pipe-flow measuring device. It was important to know at what point near the orifice the attachment should be made in order to measure correctly the pressure drop of the steam flowing through the orifice. It was thought at the time both by Mr. Bailey and the writer that an investigation would reveal many valuable point concerning the flow conditions through the orifice in a pipe. The present line of work is the final outcome of this thought and has been carried on in connection with water flow, since water could be more easily handled than steam, the intention being to continue later with a study of the flow conditions in a steam line. The work was done in the hydraulics laboratory of the Ohio State University. The experiments on the orifice diaphragms in the pipe formed the thesis of H. J. and W. W. Watson, of the Class of 1915, in Mechanical Engineering, for whose able assistance within the past year credit is hereby duly given.

The paper is really a record of progress, for only a few points have been touched upon, such as the pressure changes in the vicinity of the diaphragm, or orifice; the probable location of the least section, or zone of greatest velocity of the water jet; and the working coefficients of the diaphragms; leaving many other points of equal interest and importance to be studied later. The experiments were confined to one size of water pipe (5-in.) and the pressure drop through the diaphragm did not run much in excess of 6 ft. of water, which was considered to be the probable maximum drop desirable to use in connection with any automatic registering device. For the largest diaphragm this range of pressure drop gave a maximum velocity of 17.5 ft. per sec.

SYNOPSIS

A series of experiments was made on 5-in. pipe orifices, both cap orifices and orifices inserted in a 5-in. pipe flange placed in a horizontal water line.

The purpose of the tests were:

a To study the pressure relations existing in the vicinity of an orifice in a pipe in order to determine the most suitable point of attachment for manometer connections.

b To note the position of greatest pressure drop due to flow through the orifices.

c To obtain reliable coefficients of discharge for the orifices.

The orifice diaphragms (of Monel metal, outer edge corrugated to form gasket) ranged from 4.5 in. diameter to 1 in. diameter in ½-in. steps, giving a series of 90 to 20 per cent pipe diameter sizes with concentric openings. Two sizes of eccentric and segmental diaphragms having offset orifice openings equal in area to the 90 and 80 per cent diameter sizes were also tested.

Pressure connections were made on each side of the pipe at six points in one pipe diameter above the diaphragm and at eleven points at varying distances in five pipe diameters below the diaphragm. A series of curves have been plotted showing the pressure variation between a fixed point above and the various points below the diaphragm.

Coefficients of discharge have been computed from volumetric measurement of the water discharged by the orifices. Discharge curves are also included for all the pipe orifices, plotted on logarithmic coördinate paper for ready reference.

The average diaphragm coefficients range from 0.602 to 0.706 and the 5-in. cap orifice coefficients range from 0.610 to 0.637 for the 40 to 90 per cent orifices.

The conclusions reached in the paper are:

1 The plate orifice in pipe is as reliable for flow measurement as the ordinary thin plate orifice.

2 The point of maximum pressure drop is at about ½ pipe diameter from the diaphragm.

3 The eccentric and segmental orifices increase the pressure drop reading, but more care is necessary in making pressure connections.

4 The best point for pressure connection is not less than ½ pipe diameter below diaphragm and not less than 1 pipe diameter distance above the diaphragm.

5 For steady flow conditions the 80 per cent size should not be exceeded.

6 The average coefficient of discharge for the 5-in. pipe diaphragm agrees very closely with that for the 5-in. pipe cap orifice.

7 The coefficients of the pipe diaphragm vary more nearly in accord with the variation in size of diaphragm orifice than those for the 5-in. pipe cap orifice.

8 The agreement is closer for all the pipe orifices at about 80 per cent diameter ratio.

9 The point of maximum velocity of flow is apparently a function of the pipe diameter and not of the diameter of the diaphragm orifice.

10 The restoration of pressure on the downstream side of the diaphragm is apparently a function of the area of the diaphragm.

Presented at the Spring Meeting of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, New Orleans, La., April, 1916. Pamphlet copies without discussion may be obtained; price 15 cents to members, 30 cents to non-members.

PURPOSE OF THE TESTS

In general, the purpose of the tests was

a To discover the pressure relations existing immediately above and below an orifice diaphragm in a pipe in order to determine the most suitable points for making the pressure connections (for the manometer).

b To note the position of greatest pressure drop due to flow through the orifice, or the probable point of greatest velocity, corresponding to the point of least section of a jet of water flowing freely into the air.

c To obtain reliable coefficients of discharge for orifice diaphragms of different diameters.

THE EQUIPMENT

For these experiments a horizontal line of 5-in. standard pipe was used, approximately 42 ft. long, in which was located an extra-heavy flanged coupling for holding the orifice diaphragms. The heavy coupling was not required for strength, but was employed to allow the use of diaphragms adapted for

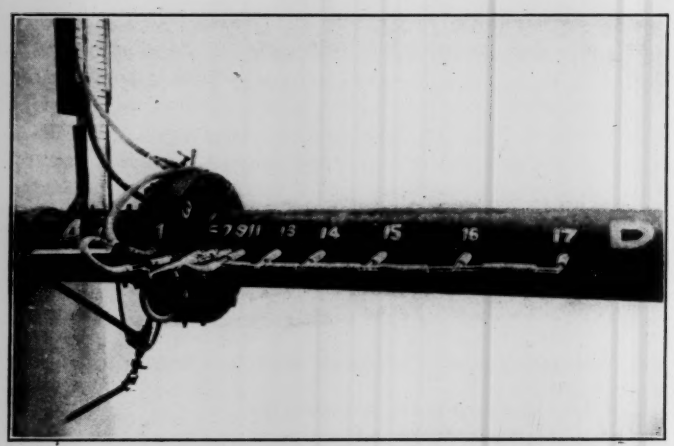

FIG. 1 MANIFOLD AND MANOMETER CONNECTIONS AT THE DIAPHRAGM FLANGE

high-pressure pipe and fittings. In Fig. 1 is a view of the pipe, flanges and manometer connections, and from the diagram in Fig. 4 it will be noted that the location of the diaphragm is 21 ft. 11 in. below an ell and 20 ft. 2 in. from the discharge end of the pipe, on which is screwed a cap having a discharge orifice. Water was supplied to the pipe line by a 6-in. centrifugal pump direct-connected to a steam turbine. The water was measured by means of several large measuring bays.

The diaphragms were all formed from plates of Monel metal $^1/_{32}$ in. thick, with the outer rings of their surfaces, above 5.1 in. diameter, corrugated to form a tight joint between the flanges, without the use of gaskets. The orifices were bored out accurately to size and were of three types: (1) Concentric with the rim of the diaphragm; (2) eccentric with the rim; and (3) segmental.

There were eight concentric diaphragms and two each of the eccentric and segmental diaphragms. The concentric diaphragms had orifices ranging from 4.5 in. diameter to 1 in. diameter, by steps of 0.5 in., making a series in terms of pipe diameter of 90, 80, 70, 60, 50, 40, 30 and 20 per cent diameter sizes. The eccentric and segmental diaphragms were in two sizes, having orifices equal in area to the 90 per cent and 80 per cent concentric sizes mentioned above.

The eccentric diaphragms were made with the edge of the orifice just flush on one side with the inner surface of the pipe. The orifices of the segmental diaphragms were of the same diameter as the inside of the pipe, but had strips inserted which were so located as to produce segmental openings equal in area to the 90 per cent and 80 per cent sizes of the concentric diaphragms. The three types of diaphragms are shown in Fig. 2. These diaphragms were furnished by E. G. Bailey

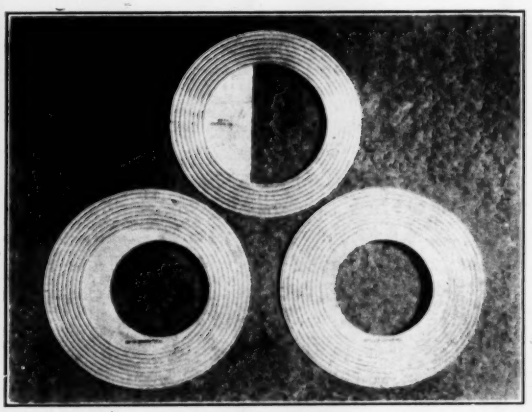

FIG. 2 TYPES OF DIAPHRAGMS USED

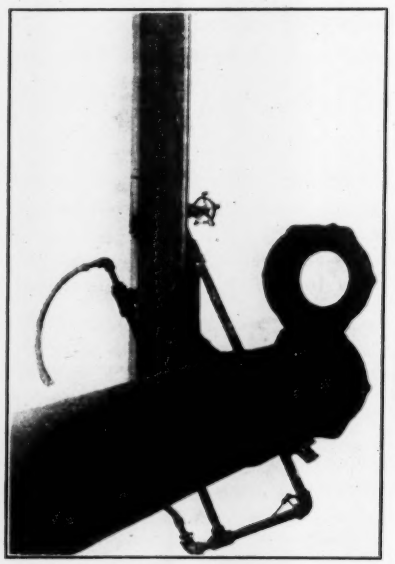

FIG. 3 ORIFICE AT END OF 5-IN. PIPE WITH MANOMETER OR GAGE GLASS CONNECTION

and are the standard form of orifice plate used in the Bailey fluid meters.

PIPE-CAP ORIFICES

Pipe-cap orifices were placed on the end of the 5-in. pipe (Fig. 3), to provide a means for regulating the water contents of the pipe below the diaphragm and so control more easily the pressure drop through the diaphragm. These orifices also gave an opportunity to secure data for computing the coefficients of discharge for this form of orifice. The pipe-

cap orifices varied in size, ranging from 4-in. diameter to 1-in. diameter by ½-in. intervals. No special refinements were practiced in finishing the caps except to bore and ream the orifices accurately to size and to smooth up the inside surfaces of the caps.

TABLE 1 OBSERVED DATA

4-in. Concentric Diaphragm with 4-in. Pipe Orifice. Run No. 18

		Drop in Pressure, Feet Water, at Position Shown							
At A	At B	Manometer			At A	At B	Manometer		
		left	right	total ft.			left	right	total ft.
[1]A5	B1	−2.23	+1.32	3.55	A5	B2	−2.33	+1.36	3.69
	3	2.30	1.33	3.63		4	2.33	1.36	3.69
	5	2.24	1.31	3.55		6	2.22	1.28	3.50
	7	2.10	1.20	3.30		8	1.94	1.07	3.01
	9	1.79	1.00	2.79		10	1.71	0.90	2.61
	11	1.58	0.82	2.40		12	1.55	0.77	2.32
	13	1.28	0.58	1.86		13	1.30	0.58	1.88
	14	1.15	0.46	1.61		14	1.15	0.45	1.60
	15	1.06	0.40	1.46		15	1.07	0.38	1.45
	16	1.05	0.38	1.43		16	1.01	0.34	1.35
[1]	17	−1.04	+0.40	1.44		17	−1.03	+0.35	1.38
[1]A1	B14	−1.27	+0.57	1.84	A2	B14	−1.22	+0.52	1.74
3		1.18	0.47	1.65	4		1.17	0.46	1.63
5		1.16	0.43	1.59	6		1.15	0.44	1.59
7		1.15	0.42	1.57	8		1.15	0.45	1.60
9		1.12	0.39	1.51	10		1.16	0.46	1.62
[1]11		−1.14	+0.42	1.56	12		−1.13	+0.45	1.58

4-in. Eccentric Diaphragm with 4-in. Pipe Orifice. Run No. 22

[1]A5	B1	−1.98	+1.96	3.94	A5	2	−1.33	+1.43	2.76
	3	2.04	2.01	4.05		4	1.58	1.65	3.23
	5	2.12	2.06	4.18		6	1.60	1.65	3.25
	7	2.06	2.01	4.07		8	1.72	1.78	3.50
	9	1.96	1.93	3.89		10	1.80	1.67	3.47
	11	1.82	1.86	3.68		12	1.58	1.68	3.26
	13	1.51	1.54	3.05		13	1.50	1.56	3.06
	14	1.20	1.32	2.52		14	1.18	1.32	2.48
	15	1.01	1.16	2.17		15	1.02	1.08	2.10
	16	0.86	1.05	1.91		16	1.88	1.07	1.95
[1]	17	−0.83	+1.03	1.86		17	−0.83	+1.06	1.83
[1]A1	B14	−1.21	+1.35	2.56	A2	B14	−0.80	+0.81	1.61
3		1.20	1.35	2.55	4		0.92	1.01	1.93
5		1.11	1.23	2.34	6		0.92	1.01	1.93
7		1.10	1.16	2.26	8		1.07	1.17	2.24
9		1.04	1.12	2.16	10		1.07	1.16	2.23
[1]11		−1.05	+1.16	2.21	12		−1.13	+1.21	2.34

4-in. Segmental Diaphragm with 4-in. Pipe Orifice. Run No. 26

A5	B1	−2.40	+1.97	4.37	A5	B2	−1.53	+1.35	2.88
	3	2.44	2.00	4.44		4	1.92	1.63	3.55
	5	2.49	2.05	4.54		6	2.01	1.67	3.68
	7	2.47	2.05	4.54		8	2.14	1.81	3.95
	9	2.50	2.07	4.57		10	2.12	1.79	3.91
	11	2.45	2.00	4.45		12	2.16	1.80	3.96
	13	2.13	1.80	3.93		13	2.05	1.70	3.75
	14	1.69	1.42	3.11		14	1.66	1.43	3.09
	15	1.36	1.22	2.38		15	1.40	1.25	2.65
	16	1.21	1.09	2.30		16	1.20	1.05	2.25
	17	−1.15	+1.03	2.28		17	−1.17	+1.02	2.19
A1	B14	−1.56	+1.35	2.91	A2	B14	−1.02	+0.60	1.62
3		1.63	1.44	3.07	4		1.26	0.95	2.21
5		1.64	1.40	3.04	6		1.30	1.02	2.32
7		1.60	0.32	1.92	8		1.38	1.12	2.50
9		1.55	1.23	2.78	10		1.41	1.18	2.59
11		−1.55	+1.25	2.80	12		−1.41	+1.18	2.59

[1] Static gage at A = 6.0

PRESSURE CONNECTIONS

Fig. 4 shows the locations of the pressure connections for the manometer, which are spaced along lines on diametrically opposite sides of the pipe in a horizontal plane with its axis.

Above the diaphragm, on the upstream side, there are six connections on each side of the pipe, and below the diaphragm there are 11 connections. It will be seen that on the right side of the pipe, looking downstream, the pressure connections begin at a point located ½ in. from the plane of the diaphragm and that the first six connections are spaced 1 in. apart; while the remaining five points on the downstream side are spaced respectively 2½, 3, 4, 5 and 5.3 in. apart, making the last one, No. 17, five pipe diameters from the diaphragm plane.

The connections on the left side are similarly placed, except that those nearest the diaphragm are located 1 in. from it, instead of ½ in., and that the five connections farthest away from the diaphragm are placed opposite those on the right side. These connections are designated by odd numbers on the right side and even numbers on the left side, except that the five points farthest away from the diaphragm on both sides of the pipe are given numbers in order from 13 to 17 inclusive.

On the downstream side the connections were made by drilling and tapping holes for ⅛-in. brass air cocks which were screwed into the pipe until their ends were flush with the inside. These air cocks have openings $^{3}/_{16}$ in. in diameter. A

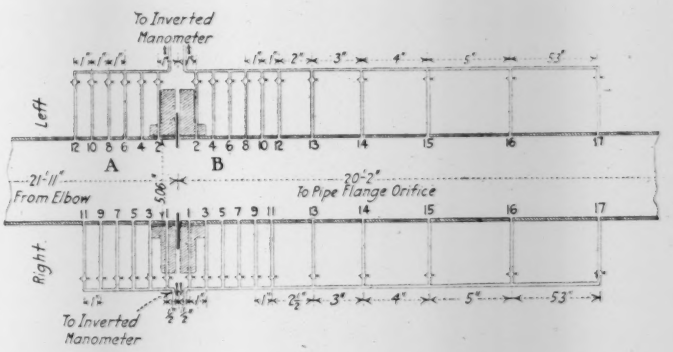

FIG. 4 POSITION OF DIAPHRAGM FLANGE AND POINTS OF PRESSURE CONNECTIONS

manifold formed with glass tees and heavy rubber tubing led from these pressure connections to one side of a water manometer 7 ft. in length, the bottom of which is shown in Fig. 1. The glass connections made it possible to see whether the tubes were free from air pockets.

On the upstream side air cocks of the same size were used, but the nipple connections leading to the air cocks were plugged and then drilled with holes of only ⅛ in. in diameter. The manifold for the upstream side was formed from a rigid brass bar, to which the air cocks from the pipe were connected by nipples and from which a rubber tube led to the other side of the inverted water manometer mentioned above.

A second water-gage glass (shown in Fig. 1 with a rubber tubing leading to a connection at the bottom side of the pipe) was used to indicate the head on the diaphragm and to aid in maintaining a more constant water head.

The complete manifold arrangement (see Fig. 4) made it possible to maintain a pressure difference, or drop, between any point of connection above and any point below the diaphragm without disturbing the gage glass which indicated the head on the upstream side of the pipe.

The static head at the cap orifice was read at a point 7.5 in. from the plane of the orifice on a water column whose zero scale reading was on a level with the center of the pipe.

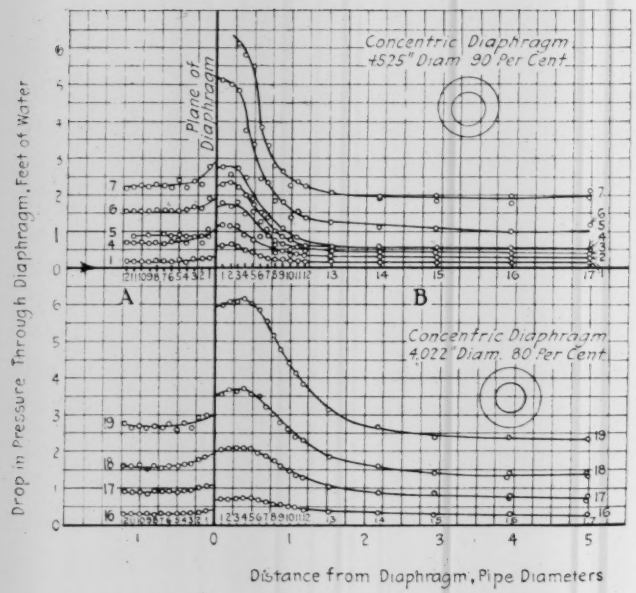

FIG. 5 80 AND 90 PER CENT CONCENTRIC DIAPHRAGMS

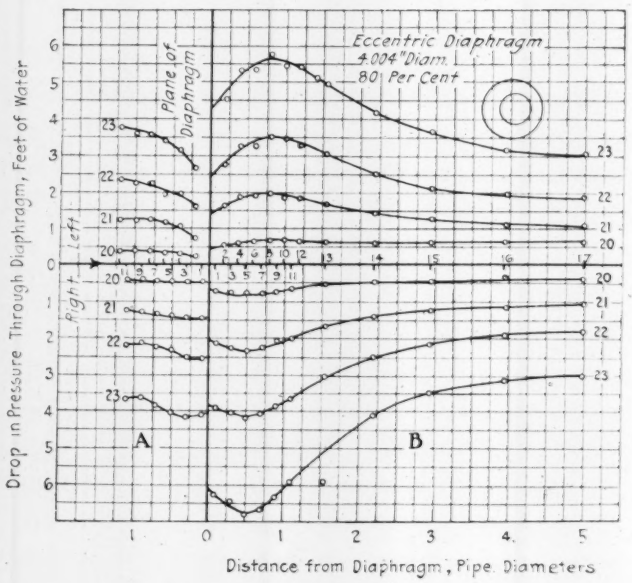

FIG. 6 80 PER CENT ECCENTRIC DIAPHRAGM

PRESSURE TRAVERSES

A series of explorations of pressures was made along the horizontal element of the pipe on each side of the diaphragm, going upstream one pipe diameter and downstream five pipe diameters. In making these explorations, or longitudinal traverses, those on the downstream or B side were all made with the upstream connection open at A-5, or one-half pipe diameter above the diaphragm (excepting for the 90 per cent concentric diaphragm, when A-10 was open). When traversing the upstream or A side, the downstream connection was open at B-14 (excepting for the 90 per cent concentric diaphragm, when B-10 was open). In this way the pressure changes in the vicinity of the diaphragm could be noted. Such traverses were made for four different pressure drops (approximately ½ ft., 2 ft., 4 ft. and 6 ft.) for the 90 to 50 per cent diaphragms inclusive; and for a 6-ft. pressure drop for the 40, 30 and 20 per cent diaphragms.

In general, the pressure head conditions could be maintained with little variation by means of the centrifugal pump. Such variation was watched and controlled by a man stationed at a valve in the supply pipe line some 50 ft. distant from the diaphragm.

During the calibration of the diaphragms and orifices the water was measured volumetrically in a calibrated cistern, or bay, of about 200 sq. ft. cross-section and 12,000 gal. capacity. A series of deflector pipes was used so that the water could be shifted into or from the measuring bay as desired.

PROCEDURE IN MAKING A TRAVERSE

The usual procedure was to bring the static pressure above the diaphragm to the desired height, and when conditions had reached a constant state and the manifold connections were found to be free from air a traverse was made of the pres-

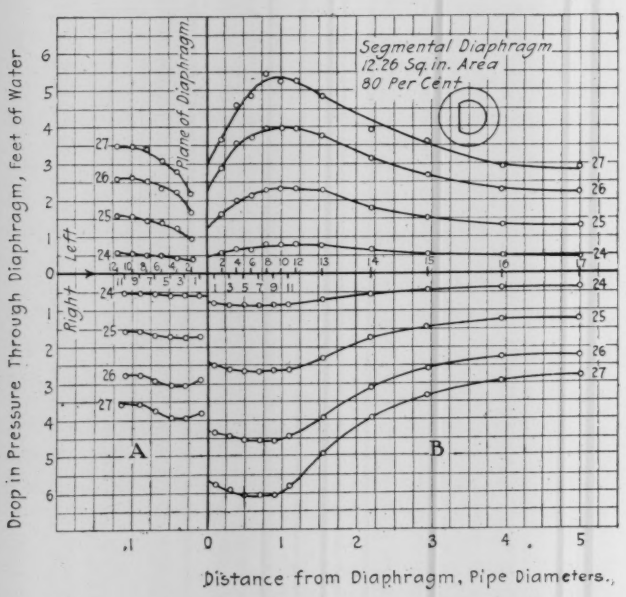

FIG. 7 80 PER CENT SEGMENTAL DIAPHRAGM

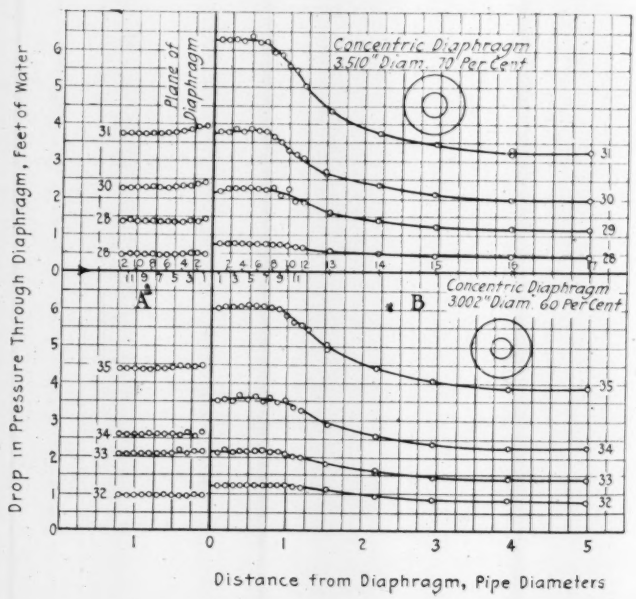

FIG. 8 60 AND 70 PER CENT CONCENTRIC DIAPHRAGMS

sure drop through the diaphragm between the fixed point A-5 (½ pipe diameter upstream) and each point in succession on the downstream side, taking the odd-numbered points first and then following with the even-numbered pressure points.

A fixed reference point B-14 was then taken on the downstream side, and the upstream reading was explored, to get the pressure variation above the diaphragm. Each time a reading was taken the inverted manometer column was allowed to assume its state of equilibrium. The height of the water in the two lengths of the manometer was read simultaneously by two observers at a given signal. The whole traverse required from 10 to 15 minutes.

TABLE 2 OBSERVED DATA

Calibration of 4-in. Concentric Diaphragm and 4-in. Pipe Orifice. Run No. 16

Time, Min.	Head at orifice, ft.	Head at A, ft.	Manometer A5 to B5 left	Manometer A5 to B5 right	Manometer A5 to B5 total	Manometer A1 to B1 left	Manometer A1 to B1 right	Manometer A1 to B1 total	Volume Scale	Cu. Ft.
0	3.77	6.15	−2.36	+1.10	3.46	−2.36	+1.10	3.46	0.8	−23
	3.78	6.15	2.40	1.12	3.52	2.38	1.08	3.46		
3	3.78	6.15	2.41	1.09	3.50	2.36	1.06	3.42	1.84	
			2.38	1.05	3.43	2.37	1.02	3.49		
6	3.71	6.10	2.43	1.07	3.50	2.39	1.01	3.40	2.90	
			2.43	1.07	3.50	2.41	1.03	3.44		
9	3.71	6.10	−2.50	+1.03	3.53	−2.41	+0.96	3.37	3.95	574
	3.77									
avg.	3.748				3.50			3.47	total	597
							Cu. ft.	per	sec. =	1.105

Calibration of 4-in. Eccentric Diaphragm and 4 -in. Pipe Orifice. Run No. 20

0	3.60	6.00	−2.07	+2.03	4.10	−2.00	+1.95	3.95	4.39	778
			2.02	2.00	4.02	2.00	2.00	4.00		
3			2.04	1.99	4.03	2.02	1.98	4.00	5.95	
	3.52	6.00	2.13	2.01	4.14	2.04	1.96	4.00		
6			2.02	1.92	3.94	2.01	1.94	3.95	6.98	
	3.55	5.95	2.10	1.95	4.05	2.04	1.93	3.97		
8.58	3.55	5.95	−2.15	+1.97	4.12	−2.00	+1.90	3.90	8.00	1351
avg.	3.555				4.057			3.967	total	573
							Cu. ft.	per	sec. =	1.065

Calibration of 4-in. Segmental Diaphragm and 4-in. Pipe Orifice. Run No. 24

0	3.48	5.90	−2.58	+2.01	4.59	−2.40	+1.83	4.23	0.70	−42
			2.60	2.00	4.60	2.38	1.82	4.20		
3	3.44	5.90	2.55	1.95	4.50	2.36	1.83	4.19	1.70	
	3.52	6.00	2.55	1.97	4.52	2.38	1.84	4.22		
6	3.50	5.95	2.60	1.99	4.59	2.38	1.85	4.23	2.725	
	3.50	5.95	2.54	1.96	4.50	−2.41	+1.87	4.28		
9	3.52	6.00	−2.56	+2.00	4.56				3.74	535
avg.	3.49				4.55			4.22	total	577
							Cu. ft.	per	sec. =	1.068

CALIBRATION OF ORIFICES

The flow of water was also measured, using these same diaphragms and orifices for the same pressure conditions as were maintained during the so-called traverses. In most cases, though not always, a calibration either followed a traverse or immediately preceded it, so as to have flow conditions the same. The length of the runs for the calibrations ranged from 9 to 30 minutes, depending on the quantity of water discharged by the orifices. The readings were taken in many cases every minute of the pressure drop between A-5 and B-5, A-1 and B-1, and also of the head at the pipe orifice. These readings were taken in rotation and formed entirely independent observations. For the large-sized diaphragms more time was needed to take each individual reading, hence fewer readings in all could be taken. The time readings were all taken on a stop watch whose accuracy was checked.

DATA SECURED FROM TESTS

Only one set of data is included in this paper, since the same scheme was pursued in getting the other sets of readings. Table 1 shows the data taken for the 4-in. diaphragms, or the 80 per cent sizes. This includes, besides the data for the concentric orifice, or diaphragm, those for the eccentric and segmental diaphragms. Table 2 shows the observations during the calibrations of these same diaphragms, taken for the quantity of water discharged at the same or nearly the same rates of flow. In this table are included the pressure drops between points A-5 and B-5; between A-1 and B-1; and also the head readings at the pipe orifice; and the cubic feet of water discharged per run, together with the quantity in cubic feet per second.

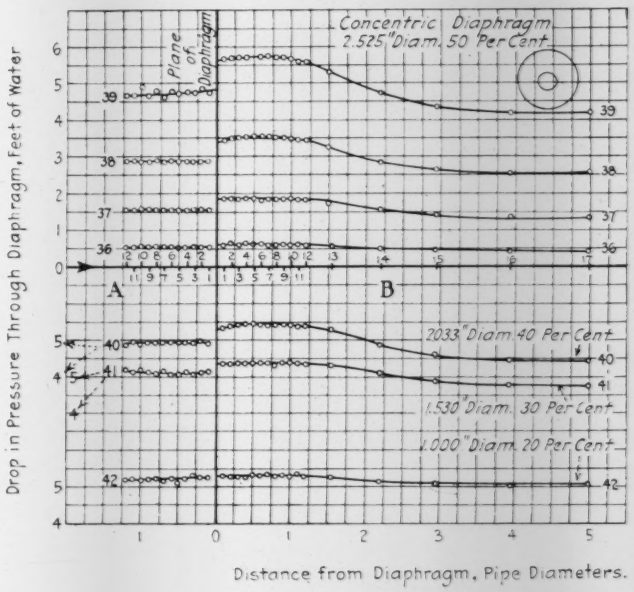
Concentric Diaphragm
2.525" Diam. 50 Per Cent.
Plane of Diaphragm
2033" Diam. 40 Per Cent.
1.530" Diam. 30 Per Cent.
1.000" Diam. 20 Per Cent.
A
B
Drop in Pressure Through Diaphragm, Feet of Water
Distance from Diaphragm, Pipe Diameters.

FIG. 9 50, 40, 30 AND 20 PER CENT CONCENTRIC DIAPHRAGMS

The data so taken were made use of in two ways: (*a*) the observations taken during a traverse were plotted on coördinate paper to show the pressure distribution at the diaphragm, and (*b*) from the calibration data the coefficients of discharge for the diaphragms and pipe-cap orifices were computed.

PRESSURE DROP CURVES

The curves plotted in Figs. 5 to 9 inclusive show the pressure drop variation for all the diaphragms. The horizontal scale was laid off in pipe-diameter distances, and is also marked at the proper points showing the positions along the pipe where the pressure readings were taken. The vertical

scale is laid off to represent pressure drop through the diaphragm in feet.

To illustrate: Run No. 18, Table No. 1 (4.022-in. concentric diaphragm) gives the reading from which curve No. 18 (Fig. 5) was plotted. A and B indicate the location of the points above and below the plane of the diaphragm. The upstream connection was A-5 (one-half pipe diameter above diaphragm) and is considered as a zero pressure point. Starting with B-1, the pressure drop of 3.55 ft. is laid off upwards. For B-3 and B-5 the pressure drops are 3.63 and 3.55 respectively, and so on. On the A side of the diaphragm are laid off the pressure drops between B-14 (as fixed point) and each point in succession as shown in Run 18, Table 1, by A-1 = 1.84 ft., A-3 = 1.65 ft., A-5 = 1.59 ft., and so on.

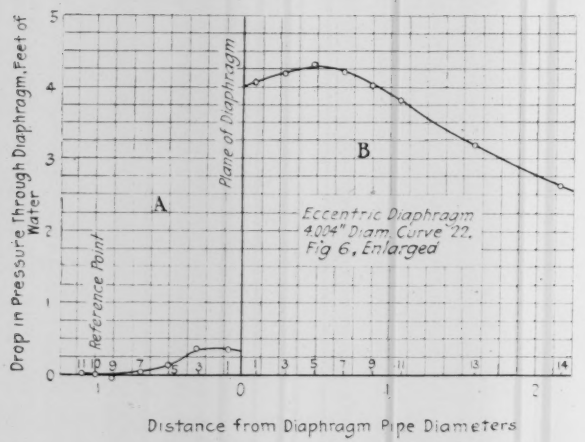

FIG. 10 CURVE NO. 22, FIG. 6 ENLARGED. ECCENTRIC DIAPHRAGM

For the concentric diaphragms the pressure-drop readings for both the right and left sides of the pipe are plotted together and form a single curve, as shown by curve No. 18 (Fig. 5). The eccentric and segmental diaphragms, however, have a different pressure drop for each side of the pipe and have been plotted separately, as may be seen in curves Nos. 20 to 23 (Fig. 6) for the 80 per cent eccentric diaphragms, where the curves for the right side of the pipe have been placed below and those of the left side above the center line of the curve sheet.

The curves for the A side of the diaphragm have been plotted as read from the data, and, since A-5 was taken as a zero point for the downstream side of the diaphragm, all points on the A side should start at A-5 as zero; but if so plotted, it was feared that a confusion of curves would result, hence they are separated on the diagram and are intended to show only a relative change in pressure and not the absolute change above the diaphragm.

For the special diaphragms, viz., the eccentric and segmental, enlarged curves have been plotted from the observed data (*e.g.*, Fig. 10), on which the readings on the A side have been corrected so as to start from A-10 as the zero reference point; these curves will show the actual pressure drop between the two sides of the diaphragm.

For example: Fig. 10 (plotted from Run 22, Table 1), giving curve No. 22 (Fig. 6) for the 80 per cent eccentric diaphragm, shows the true pressure relations when A-10 is taken as the zero point. From the data for Run 22, Table 1, the pressure drop between A-5 and B-5 equals 4.18 ft.; the pressure drop between A-10 and A-5, as read from curve No. 22 enlarged (Fig. 10), equals 0.13 ft.; the plotted point for the pressure drop between A-10 and B-5 (curve No. 22, Fig. 10) will then equal 4.18 + 0.13 = 4.31 ft. The other points are found in a similar manner.

FORMULA FOR COEFFICIENT OF DISCHARGE

In computing the coefficients of discharge, the pipe orifices were considered as frictionless or thin-plate orifices having a velocity of approach. Hence the total head acting on the diaphragm will be:

Total head = Static head + velocity head

$$h = \frac{V^2}{2g} = H + \frac{v^2}{2g} = H + \frac{V^2}{2g}\left(\frac{A_2}{A_1}\right)^2 \quad \ldots\ldots\ldots\ldots [1]$$

Since $Q = A_1 v = A_2 V$

$$v^2 = \left(\frac{A_2}{A_1}\right)^2 V^2$$

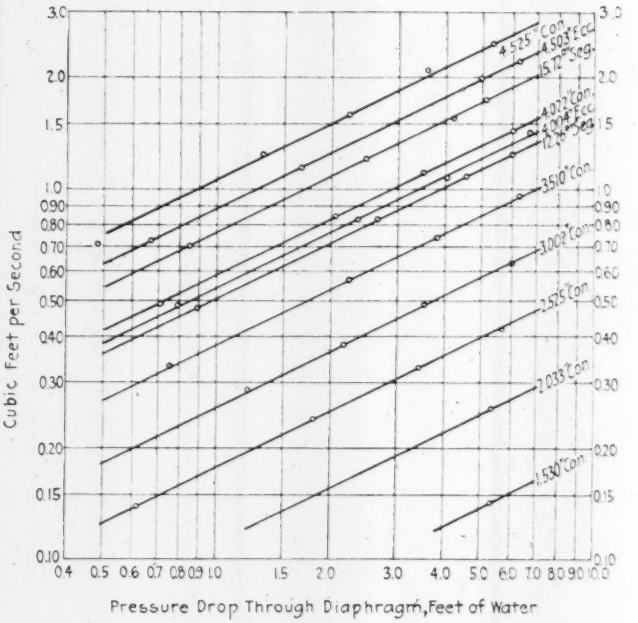

FIG. 11 DISCHARGE CURVES IN CU. FT. PER SEC. FOR DIAPHRAGM IN 5-IN. WATER PIPE

Then from [1]

$$\left[1 - \left(\frac{A_2}{A_1}\right)^2\right] V^2 = 2gH$$

$$V = \sqrt{2gH} \div \sqrt{1 - \left(\frac{A_2}{A_1}\right)^2} \quad \ldots\ldots [2]$$

Introducing coefficient of discharge K

$$q = \frac{K A_2 \sqrt{2gH}}{\sqrt{1 - \left(\frac{A_2}{A_1}\right)^2}}$$

$$K = \frac{q\sqrt{1 - \left(\frac{A_2}{A_1}\right)^2}}{A_2\sqrt{2gH}} = \frac{q}{A_2\sqrt{2gH}} F \ldots [3]$$

In the above formulæ:

h = total acting head on the diaphragm
V = velocity through diaphragm
v = velocity through pipe
A_2 = area of diaphragm
A_1 = area of pipe
q = actual discharge through diaphragm
Q = theoretical discharge through diaphragm
K = coefficient of discharge through diaphragm
F = factor of correction for velocity of approach

$$= \sqrt{1-\left(\frac{A_2}{A_1}\right)^2}$$

H = drop through diaphragm or orifice

In the formula no attempt has been made to correct for the contraction of the stream as has been done by some experimenters[1] in hydraulics, since it is believed that the simpler formula will best serve the purpose in finding the coefficients and in their application.

The factor of correction (F) in the formula may be read directly from the curve for velocity of approach in Fig. 15.

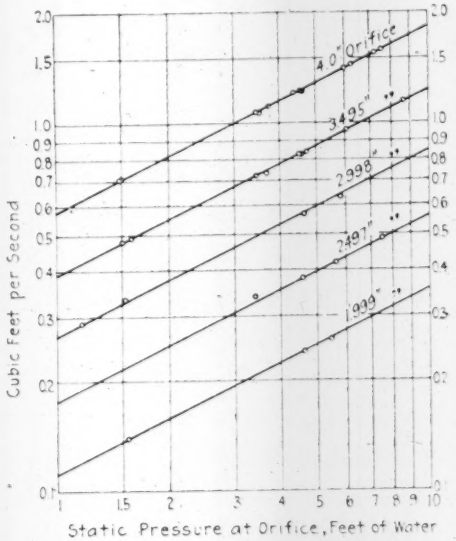

FIG. 12 DISCHARGE CURVES IN CU. FT. PER SEC. FOR ORIFICES ATTACHED TO 5-IN. WATER PIPE

For the diaphragm the drop in pressure was taken at two points, the first at A-5, B-5; the second at A-1, B-1. This was done so as to compare coefficients of discharge for a point close to the diaphragm with a point some distance away from the diaphragm and which is a better point at which to make an attachment.

Curves have also been plotted on logarithmic coördinate paper between the cubic-feet-second discharge and the pressure drop through the diaphragms (see Fig. 11). Similar curves are also given for the 5-in. pipe cap orifices (see Fig. 12).

The coefficients of discharge for the diaphragms and the 5-in pipe-cap orifices are to be found in Tables 3 and 4. Other coefficients of discharge for pipe-cap orifices are given in Table 5. These coefficients are computed from results obtained from experiments made by Prof. R. S. King, Mem.Am. Soc.M.E., University of Arizona, and the writer some years ago. They are given for the purpose of comparison with the results obtained from the 5-in. pipe orifices.

These results, which were obtained from the calibrations of orifices attached to 3-in. and 4-in. water pipes, have been used repeatedly since then, and together with the discharge curve sheets have been found of great value in measuring quantities of water up to 1000 gal. per min. The curve sheets are given in Figs. 16 and 17 with the thought that other members of the Society may also find them useful.

A comparison of the coefficients of discharge for the series of pipe orifices, including the diaphragms and the pipe-cap orifices, can be noted in Fig. 13, and also in Table 6. The

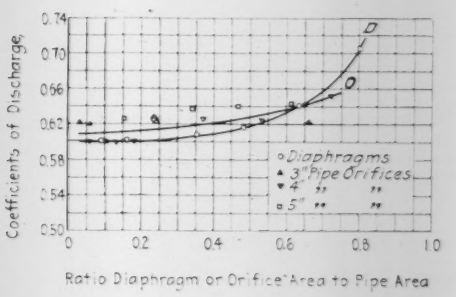

FIG. 13 COEFFICIENTS OF DISCHARGE FOR PIPE ORIFICES

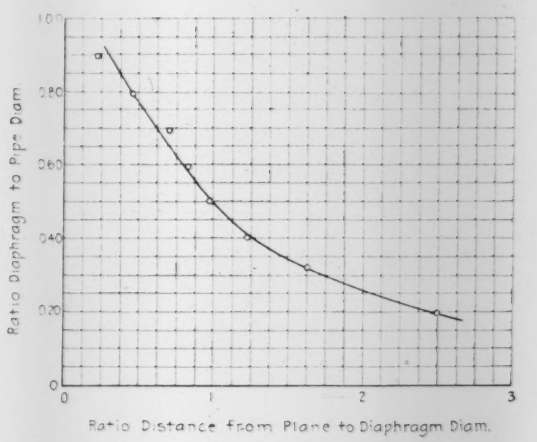

FIG. 14 PROBABLE POSITION OF LEAST SECTION AS SHOWN BY LOCATION OF GREATEST PRESSURE DROP THROUGH CONCENTRIC DIAPHRAGMS

coefficients for the 5-in. pipe orifices, including both the diaphragm orifices and the pipe orifice, show a more uniform variation through the range of head maintained than is found for the coefficients as computed for the 3-in. and 4-in. pipe-cap orifices. This uniform variation is partly accounted for by the fact that more runs were made for the low range of head with the 5-in. pipe orifices than for the 3-in. and 4-in. cap orifices.

The average diaphragm coefficients range from 0.602 to 0.706, while the average coefficients for the 5-in. cap orifices range from 0.610 to 0.637 for the 40 to 90 per cent orifices respectively. For the 80 per cent 5-in. pipe-cap orifice the coefficients agree very closely (Table 4) with an average value of 0.646, as compared with a probable average value of 0.629 for the 3-in. and 4-in. cap orifices for 80 per cent orifices. For the 5-in. pipe orifices the coefficients for the orifices below the 80 per cent size average 0.608 for the diaphragms and 0.622 for all the cap orifices, or a difference of about 2.3 per

[1] Proc. Inst. Civil Engineers, vol. 197, p. 243, "The Diaphragm Method of Measuring the Velocity of Fluid-Flow in Pipes," by Holbrook Gaskell, Jr.

cent, which is relatively a small variation and would seem to indicate that the behavior of water in passing through the diaphragm is very similar to that of a jet of water issuing from a thin-plate, or frictionless, orifice, into the air.

The variation of the coefficients of discharge may also be seen from Fig. 13, where *O* is the average curve for the cap orifices and *D* the average curve for the diaphragms. It will be seen that the average curve for the cap orifices coincides with the curve for the diaphragms at about 0.640, which is equivalent to 80 per cent pipe diameter.

COEFFICIENTS FOR SPECIAL ORIFICES

For the special orifices (80 and 90 per cent eccentric and segmental diaphragms) the coefficients, of course, run lower than for the concentric diaphragms, since the pressure drop through the diaphragm is magnified by the offset at one side. For the 90 per cent size the variation is about 14 per cent for the eccentric and 24 per cent for the segmental diaphragm.

For the 80 per cent size, as might be expected, the variation

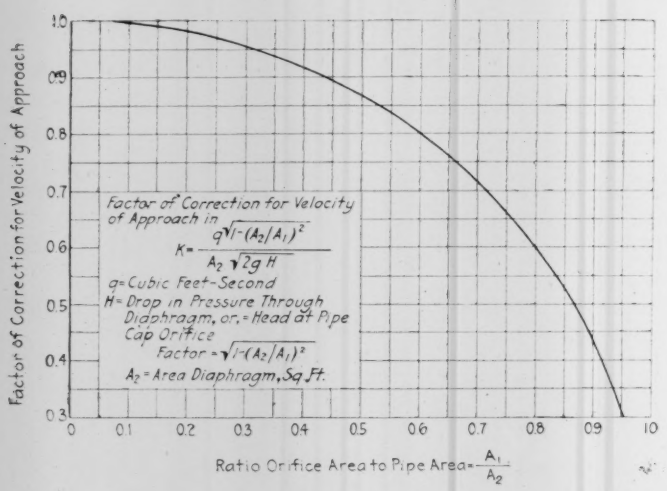

FIG. 15 FACTOR OF CORRECTION FOR VELOCITY OF APPROACH

is not so large, being 7 per cent for the eccentric and about 9 per cent for the segmental diaphragm (Table 7). Figuring the coefficient for the 80 per cent eccentric and segmental diaphragms on the basis of the average of the two pressure drops for both sides of the pipe at points ½ pipe diameter downstream, and comparing with the coefficient for the 80 per cent concentric diaphragm, the results would be as shown in Table 7.

When figured on average head, the eccentric diaphragm gives a coefficient only 1.8 per cent less than the concentric diaphragm, and the segmental diaphragm gives on the average head a coefficient 3.9 per cent less than the concentric diaphragm. This indicates that the eccentric diaphragm, especially, has very little distorting effect on the stream flow. The curves also show that for the 80 per cent eccentric diaphragm, for a point ½ pipe diameter downstream, the pressure drop is 18.8 per cent greater on one side than on the other, or a probable average magnification over the concentric diaphragm of 9.4 per cent; and for the segmental diaphragm there is a 24 per cent magnification, with a probable average of 12 per cent over the concentric diaphragm.

The coefficients of discharge for points A-1, B-1 ($\frac{1}{10}$ pipe diameter from diaphragm) for all sizes of diaphragms except the 90 per cent size, agree fairly well with those computed from points A-5, B-5 (see Table 3), running above in some cases and below in others. The coefficients run practically constant for each size of orifice for the full range of 6 ft. pressure drop.

TABLE 3 COEFFICIENTS OF DISCHARGE FOR DIAPHRAGMS

Run			Diaphragm			Pressure Drop at			Coefficient		
No.	Lgth. Min.	Readings	Kind	Diam. In.	A_2, Area, Sq. Ft.	H_5 Pressure Drop A-5, B-5 Ft.	H_1 Pressure Drop A-1, B-1 Ft.	Cu. Ft. Sec. q	K_5	K_1	K Computed from Curves
1	15	8	con-	4.525	0.1117	0.48	0.69	0.708	0.683	0.578	
2	9	4	cen-	4.525	0.1117	1.32	2.00	1.226	0.714	0.580	
3	12	6	tric	4.525	0.1117	2.24	3.40	1.573	0.704	0.571	
4	11	5		4.525	0.1117	3.62	5.46	2.085	0.733	0.597	
5	9	7		4.525	0.1117	5.34		2.446	0.718		
				(F = 0.600)							
								av.	0.710	0.582	0.706
6	15	9	eccen-	4.503	0.1106	0.67	0.73	0.725	0.615	0.584	
7	20	10	tric	4.503	0.1106	1.66	1.87	1.136	0.608	0.572	
8	9	7		4.503	0.1106	4.98	5.64	1.970	0.607	0.571	
9	10	5		4.503	0.1106	6.26	6.89	2.195	0.603	0.575	
				(F = 0.611)							
								av.	0.608	0.576	0.609
10	12	5	seg-		0.1092	0.85	0.78	0.701	0.540	0.562	
11	12	5	men-		0.1092	2.48	2.306	1.208	0.544	0.564	
12	15	8	tal		0.1092	4.21	3.73	1.554	0.537	0.570	
13	12	5			0.1092	5.11	4.72	1.728	0.541	6.564	
				(F = 0.622)							
								av.	0.541	0.565	0.542
14	15	10	con-	4.022	0.0882	0.707	0.744	0.489	0.637	0.622	
15	12	10	cen-	4.022	0.0882	2.055	2.177	0.837	0.639	0.622	
16	9	8	tric	4.022	0.0882	3.500	3.466	1.104	0.647	0.651	
17	9	7		4.022	0.0882	6.074	6.380	1.440	0.640	0.626	
				(F = 0.775)							
								av.	0.641	0.631	0.640
18	12	10	eccen-	4.004	0.0875	0.790	0.760	0.484	0.604	0.615	
19	12	9	tric	4.004	0.0875	2.361	2.279	0.824	0.594	0.605	
20	9	7		4.004	0.0875	4.057	3.967	1.065	0.586	0.593	
21	9	7		4.004	0.0875	6.720	6.570	1.410	0.601	0.609	
				(F = 0.779)							
								av.	0.596	0.606	0.598
22	12	10	seg-		0.0851	0.880	0.838	0.476	0.588	0.603	
23	12	10	men-		0.0851	2.646	2.474	0.823	0.587	0.606	
24	9	7	tal		0.0851	4.545	4.224	1.068	0.585	0.603	
25	9	8			0.0851	6.061	5.693	1.233	0.581	0.600	
				(F = 0.752)							
								av.	0.585	0.603	0.585
26	15	21	con-	3.510	0.0672	0.752	0.752	0.332	0.622	0.622	
27	15	16	cen-	3.510	0.0672	2.248	2.258	0.566	0.614	0.612	
28	12	16	tric	3.510	0.0672	3.824	3.852	0.737	0.613	0.612	
29	15	19		3.510	0.0672	6.335	6.413	0.955	0.614	0.607	
				(F = 0.877)							
								av.	0.616	0.613	0.611
30	15	18	con-	3.002	0.0492	1.217	1.210	0.288	0.618	0.619	
31	15	18	cen-	3.002	0.0492	2.166	2.166	0.379	0.610	0.610	
32	15	13	tric	3.002	0.0492	3.525	3.533	0.484	0.612	0.609	
33	18	13		3.002	0.0492	6.052	6.081	0.629	0.607	0.605	
				(F = 0.936)							
								av.	0.612	0.611	0.609
34	24	21	con-	2.525	0.0348	0.619	0.620	0.138	0.608	0.607	
35	21	21	cen-	2.525	0.0348	1.818	1.819	0.239	0.615	0.615	
36	21	21	tric	2.525	0.0348	3.459	3.462	0.327	0.610	0.610	
37	21	21		2.525	0.0348	5.727	5.721	0.419	0.606	0.607	
				(F = 0.969)							
								av.	0.610	0.610	0.611
38	27	25		2.033	0.0225	5.378	5.371	0.257	0.606	0.606	0.602
pipe at diaphragm					A_1						
				5.059	0.1396						

COEFFICIENT OF DISCHARGE FOR POINT A-10, B-5

The points at which the pressure drop was taken for computing the coefficients of discharge referred to in Table 3 were

A-1, B-1 ($\frac{1}{10}$ pipe diameter) and A-5, B-5 (½ pipe diameter) from the diaphragm. In many cases A-10 would have been a more desirable point of attachment. For the concentric diaphragms a change from that point A-5 to A-10 on the upstream side would make no appreciable change in the coefficient of discharge. For the special diaphragms there is more variation in pressure adjacent to the diaphragms on the upstream side, so that a change of from two to five per cent is shown in the coefficient of discharge in changing from A-5 to A-10 on the upstream side. Table 8 gives a comparison of coefficients of discharge for points A-5, B-5 and A-10, B-5.

TABLE 4 COEFFICIENTS OF DISCHARGE FOR ORIFICES ON 5-IN. PIPE

(Values of K are averages of from 60 to 100 readings—take over periods of 60 to 140 minutes).

Diameter of Orifice, In.	Static Head at Orifice, H Ft.	Cu. Ft. per Sec., q	K (Average)	K computed from log. curves
4.000	1.48 to 7.54	0.701 to 1.573	0.646	0.646
3.495	1.51 to 8.63	0.476 to 1.136	0.639	0.639
2.998	1.17 to 5.85	0.288 to 0.629	0.635	0.636
2.497	3.47 to 7.57	0.327 to 0.484	0.627	0.624
1.999	1.55 to 5.49	0.138 to 0.257	0.623	0.626
(of pipe, 5.113)				

TABLE 5 COEFFICIENTS OF DISCHARGE FOR ORIFICES ON 3-IN. AND 4-IN. PIPE

(Averages for Static Heads (H) of 4 ft. and 9 ft.).

	3-In. Pipe (Judd and King, 1907)					
Orifice diam., in.	0.500	0.750	1.000	1.500	2.000	2.500
K, average	0.621	0.619	0.608	0.628	0.619	0.627
	4-In. Pipe (H. Judd, 1913)					
Orifice diam., in.	0.998	1.495	1.750	2.000	2.495	2.993	3.497
K, average	0.608	0.595	0.601	0.602	0.625	0.625	0.637

Diam. of 3-in. pipe at orifice = 3.072 in.; of 4-in. pipe, 4.10 in.

TABLE 6 VARIATION OF COEFFICIENTS OF DISCHARGE FOR PIPE ORIFICES, TAKEN FROM TESTS

Kind of Orifice	Orifice Diameter Expressed in Per Cent Pipe Diameter						
	40%	50%	60%	70%	80%	90%	Av.
3-in. cap	0.608	0.628	.....	0.622	0.627	.....	0.621
4-in. cap	0.595	0.602	0.625	0.625	0.631	0.637	0.619
5-in. cap	0.626	0.624	0.636	0.639	0.646	.....	0.634
Average	0.610	0.618	0.631	0.629	0.635	0.637	0.627
Concentric diaphragm	0.602	0.611	0.609	0.611	0.640	0.706	0.630

Since from formula 3 given above the coefficient of discharge varies inversely as the square root of the head,

$$K_{10} = K_5 \sqrt{\frac{H_5}{H_{10}}} = K_5 \sqrt{\frac{H_5}{H_5 + d}} = \frac{K_5}{\sqrt{1 + \frac{d}{H_5}}}$$

K_{10} = coefficient of discharge for points A-10, B-5
K_5 = coefficient of discharge for points A-5, B-5
H_5 = pressure drop between A-5, B-5 taken as average from pressure-drop curves
d = pressure drop between A-10 and A-5 as read from enlarged pressure drop curves, or read from the observed data

Example: Referring to curve No. 22 (Fig. 10)

$H_5 = 4.28 - 0.13 = 4.15$
$= 4.15$ (as also read direct from curve No. 22, Fig. 6)
$d_5 = 0.13$ from Fig. 10
$K_5 = 0.598$ (Table 3, 80 per cent eccentric diaphragm)

$$K_{10} = \frac{0.598}{\sqrt{1 + \frac{0.13}{4.15}}} = 0.589.$$

For the concentric diaphragms, one run for each size diaphragm was selected, having a head ranging from 3.0 to 5.0 ft. and K_{10} was computed, noting the values of the pressure drop for A-5, B-5, either from the observed data or from the curves as plotted direct from the data taken. The values thus computed vary for K_{10} (Table 8) from the average values for K_5 by about 0.5 per cent. For the 90 and 80 per cent eccentric and segmental diaphragms the coefficients referred to points A-10, B-5 run from 1.6 per cent to 5.2 per cent lower than the coefficients when referred to points A-5, B-5.

TABLE 7 COMPARISON OF COEFFICIENTS, 80 PER CENT DIAPHRAGMS, 4-FT PRESSURE DROP

Kind of Diaphragm	Coefficients	Comparison of Coefficients with that for Concentric Diaphragm
Concentric	0.641 From Table 3	
Eccentric	0.596 From Table 3	7 per cent less
Segmental	0.585 From Table 3	8.7 per cent less
Eccentric	0.629 From average head for both sides of pipe	1.8 per cent less
Segmental	0.616 From average head for both sides of pipe	3.9 per cent less

TABLE 8 COEFFICIENTS OF DISCHARGE FOR CONCENTRIC DIAPHRAGMS REFERRED TO A-10

Curve No.	Diameter of Diaphragm In.	Drop in Pressure, Ft.			Coefficient		Per Cent Difference
		From Curve A-5, B-5	From Data A-10, A-5	A-10, B-5	A-5, B-5	A-10, B-5	
1	2	3	4	5	6	7	8
Concentric Diaphragms							
6	4.325	3.1	0.01	3.11	0.706	0.705	−0.2
18	4.022	3.55	0.03	3.58	0.640	0.637	−0.5
30	3.510	3.82	0.02	3.82	0.617	0.614	−0.4
34	3.002	3.59	0.03	3.62	0.609	0.606	−0.5
38	2.525	3.53	0.0	3.53	0.611	0.611	0.0
40	2.033	5.44	0.02	5.42	0.602	0.604	+0.2
41	1.530	5.35	0.06	5.29	0.603	0.607	+0.6
Eccentric Diaphragms							
10	4.503	5.15	0.35	5.50	0.608	0.588	−3.2
22	4.004	4.15	0.13	4.28	0.598	0.589	−1.5
Segmental Diaphragms							
14	area 15.72	4.13	0.48	4.69	0.542	0.514	−5.2
26	12.26	4.53	0.25	4.78	0.585	0.570	−2.6

BEST POINT FOR PRESSURE CONNECTION

An inspection of Figs. 5, 8 and 9 shows that the point of greatest drop in pressure on the downstream side of the diaphragm lies at a distance from the place of the diaphragm varying from 1 in. for the 90 per cent diaphragm to 2.5 in. for the diaphragms below the 70 per cent size. The curves for the smallest sizes and those for all the lowest heads on all the diaphragms below the 70 per cent size do not give this point of greatest pressure drop so clearly defined on the curves, although the observed data in nearly every case show a low point at 2.5 in. out from the plane of the diaphragm.

These results are shown graphically in Fig 14, in which the distance from the diaphragm is given in terms of the orifice diameter. The vertical scale gives the orifice diameters in per cent of the pipe diameter.

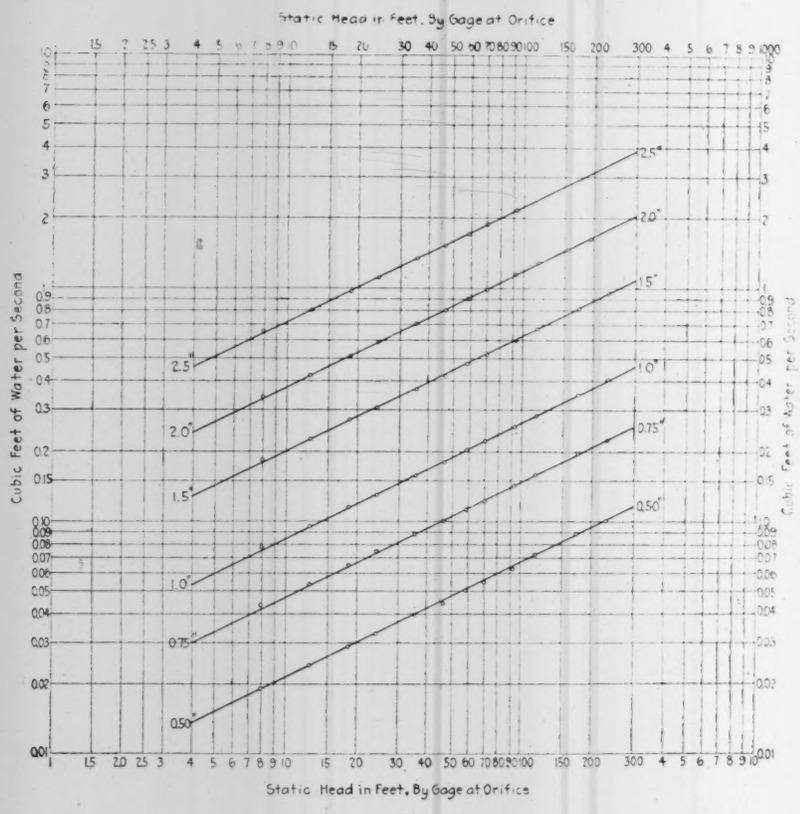

FIG. 16 DISCHARGE CURVES IN CU. FT. PER SEC. FOR FRICTIONLESS ORIFICES ATTACHED TO A 3-IN. WATER PIPE

For nearly all of the diaphragms except the 90 per cent size a point of connection for pressure readings (2.5 in. from plane) on the downstream side would give pressure drop readings varying but little from the maximum pressure drop. For the diaphragms below the 70 per cent size the range of point of connection could easily be extended to one pipe diameter distance from the place without appreciable change for pressure drops for the concentric diaphragms. On the upstream side for the concentric diaphragms the point of pressure connection could be made at any point from ½ pipe diameter to 1 pipe diameter from the plane of the diaphragm.

For the special orifices with one exception the point of greatest pressure drop lies surprisingly close to the ½ pipe diameter distance from the plane of diaphragm on the right side of the pipe, which is the side of greatest offset. For the 80 per cent segmental diaphragm the point of greatest pressure drop occurs at 3.5 in. from the plane.

On the left side of the pipe, where the edge of the diaphragm is nearly in line with the inside of the pipe, there is found, of course, a less total pressure drop than on the other side. In all cases except for the 90 per cent eccentric the point of greatest pressure drop is moved downstream to about $\frac{8}{10}$ pipe diameter, or 60 per cent more than the corresponding point on the right side. For the 90 per cent eccentric diaphragm the point of greatest pressure drop seems to lie slightly within the ½ pipe diameter distance from the plane.

On the upstream side, as might be expected with these special orifices, there is found to be a greatest pressure variation in the vicinity of the diaphragm. This difference seems to be more pronounced with the segmental orifice, due probably to the increase of swirling and eddying as the water suddenly changes its direction sidewise on approaching these offset diaphragms, in addition to the sudden contraction it undergoes in passing through the orifice. In view of these disturbances the curves show that the upstream pressure connection should not approach the diaphragm nearer than 1 pipe diameter, to secure steadiness of pressure-drop readings.

It is also plain to be seen that for the diaphragms above the 70 per cent size there is more need of care in making a pressure connection to keep close to the ½ pipe diameter distance from the plane in order to avoid sudden pressure changes. It is also quite evident that for pressure drops through the diaphragm above 3 ft. the 90 per cent diaphragm would likely give unsteady readings, owing to rapid pressure changes, unless the downstream connection could be made as close as 1 in. from the plane of the diaphragm.

Some experiments along this same line have recently been made in England by Holbrook Gaskell, Jr. (*op. cit.*) on water flow in 6-in. and 8-in. cast-iron water pipes. Mr. Gaskell states that the point of connection may be made at any point within 1½ in. from the plane of the diaphragm. It is not usually convenient to make a pressure connection even at 1½ in. distance from the diaphragm, hence it would seem advisable to use a diaphragm of not over 80 per cent size so as to allow the pressure connections to be made not nearer than ½ pipe diameter from the diaphragm. This would also insure more steady flow conditions.

ZONE OF MAXIMUM VELOCITY

Since the pressure drop must be largely due to increase of velocity, because of contraction of the jet of water on leaving the orifice, the point of least pressure would be at the zone of greatest contraction; that is, the zone where the water is moving most rapidly. The contour of the pressure-drop curves would seem to indicate a jet of moving water whose shape must somewhat resemble the jet of water issuing into the air from an orifice. The curve in Fig. 14 is plotted to indicate the position of this so-called least action.

Its distance from the diaphragm, expressed in orifice diam-

eter distances, is seen to increase as the diaphragm diameter decreases, although the actual distance does not vary much from ½ pipe diameter from the diaphragm plane. It is difficult to say whether or not the point of maximum pressure drop would be found at ½ pipe diameter distance for all diameters of pipes. The pressure-drop curves show that the pressure has reached in nearly every case its maximum amount of restoration at about 4 pipe diameters from the diaphragm for all concentric diaphragms below the 70 per cent size. For these sizes the maximum pressure drop occurs at ½ pipe diameter from the diaphragm, which would seem to indicate that for area ratios of 50 per cent and under the pipe itself has more influence on the point of greatest pressure drop than the size of the diaphragm opening.

TABLE 9 PER CENT PRESSURE RESTORATION

Size of diaphragm	Per cent restoration of initial pressure	Size of diaphragm	Per cent restoration of initial pressure
90 per cent concentric	77.0	30 per cent concentric	11.0
80 per cent concentric	62.0	20 per cent concentric	4.0
70 per cent concentric	48.0	90 per cent eccentric	65.0
60 per cent concentric	35.0	80 per cent eccentric	57.0
50 per cent concentric	30.0	90 per cent segmental	65.0
40 per cent concentric	20.0	80 per cent segmental	54.0

than ½ pipe diameter from the diaphragm on the downstream side, and not less than 1 pipe diameter from the diaphragm on the upstream side of the pipe.

AMOUNT OF PRESSURE RESTORATION

The amount of pressure restoration after passing through the diaphragm will average as given in Table 9.

An example will serve to show how the per cent of pressure restoration was found. From Curve No. 18, Fig. 5, 80 per cent concentric diaphragm, the maximum drop in pressure through the diaphragm = 3.7 ft.

The drop in pressure at B-16, point of greatest restoration = 1.36 ft.

$$\text{Per cent of restoration} = \frac{3.7 - 1.36}{3.7} = 63.3.$$

Average per cent for four heads = 62.0 (from Table 9).

After the water has passed the contracted section of the jet its velocity is somewhat gradually reduced, which causes a restoration of pressure similar to the action in a venturi tube. For all the concentric diaphragms the pressure is entirely restored at a distance of 4 pipe diameters, and for the special diaphragms the restoration of pressure is nearly if not quite completed at 5 pipe diameters distance from the plane of the diaphragm. The restoration of pressure appears to be nearly proportional to the area of the diaphragm.

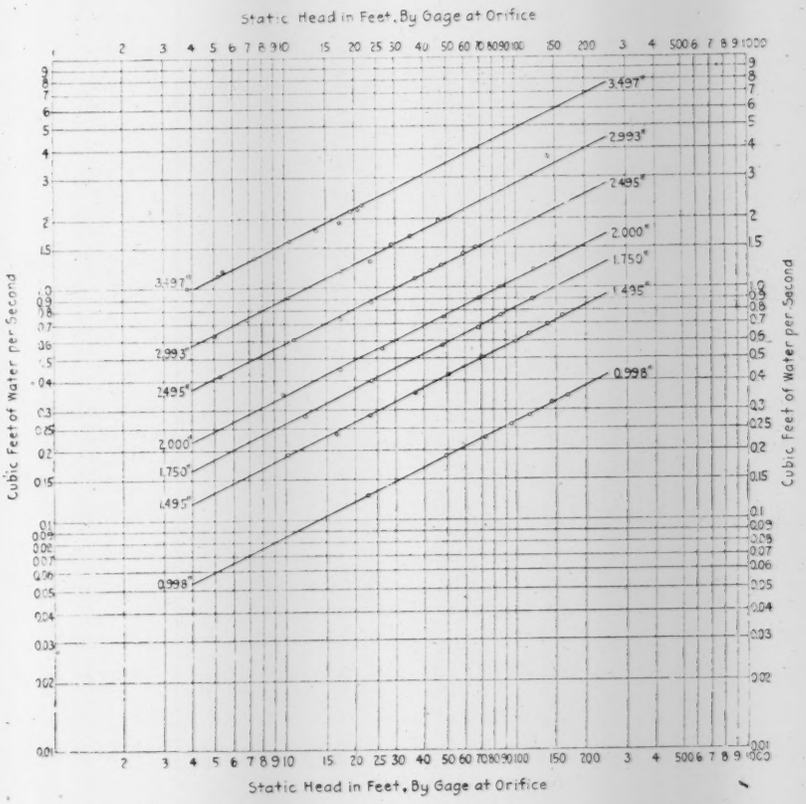

FIG. 17 DISCHARGE CURVES IN CU. FT. PER SEC. FOR FRICTIONLESS ORIFICES ATTACHED TO A 4-IN. WATER PIPE

CONCLUSIONS

In conclusion the results of these experiments would seem to bring out the following points:

1 A thin plate orifice inserted in a pipe is as reliable for flow measurement as the thin plate, or frictionless orifice, as used ordinarily.

2 The shape of the pressure-drop curves indicates a maximum point at about ½ pipe diameter from the diaphragm, which would seem to indicate a zone of maximum velocity of flow.

3 The eccentric and segmental diaphragms are advantageous in that they increase the drop reading, but more care is necessary in making the pressure connections, especially on the upstream side of the diaphragm.

4 The best point for the pressure connection is not less

5 The 80 per cent diameter size of diaphragm should not be exceeded to secure uniform flow conditions and to insure steady pressure-drop readings.

6 The average coefficient of discharge for a 5-in. pipe diaphragm agrees very closely with the average coefficient of discharge for the 5-in. pipe cap orifice.

7 The coefficients for the pipe diaphragms vary more nearly in accord with the variation in size of diaphragm orifice than those for the pipe-cap orifices.

8 The agreement is closer for the coefficients for all the pipe orifices at about 80 per cent diameter ratio.

9 The point of maximum velocity of flow is apparently a function of the pipe diameter and not of the diameter of the diaphragm orifice.

10 The restoration of pressure on the downstream side of the diaphragm is apparently a function of the area of the diaphragm.

DISCUSSION

SANFORD A. MOSS (written). There is no doubt that orifices in thin plates or pipe diaphragms are accurate and valuable instruments in many cases. It must be borne in mind, however, that in some cases the venturi meter and orifice with gradual approach offer superior advantages. The most important one is the matter of calibration. A properly shaped convergent orifice or venturi meter with a smooth and gradual entrance and a proper parallel portion for sizing the jet has a velocity coefficient of about 0.99 for all cases whatever, whether for liquids, steam, air or gas, and whether for relatively small differentials where the incompressible fluid formula $V = \sqrt{(2gh)}$ can be used, or for relatively large differentials where the accurate thermodynamic formula has to be used. On the contrary, for thin-plate orifices, calibration has to be made for all of the different cases.

In the case of the measurement of flow of air and gas in pipes, there is often the problem of securing a differential of sufficient magnitude to give satisfactory readings. If a venturi meter is used the differential can be made properly large without causing any serious net pressure drop. The net pressure loss due to a good venturi meter with large differential and 3 to 1 ratio is in the neighborhood of 1/5 of the differential. That is, 80 per cent of the differential is restored. This is to be compared with the figure of about 11 per cent given by Mr. Judd. For cases where the pipe pressure is high, so that a satisfactory differential can be secured with a total pressure drop which is a small percentage, the thin-plate orifice is satisfactory. With lower pressures, however, where pressure drop is more important, it is necessary to use a venturi meter because it gives very much less drop.

The formation of scale in a boiler may be prevented, it is stated, by applying a coat of aluminum paint to its inside surface.

Spent hemlock tan bark as it is discharged from the leach has a fuel value of 60 cents per ton when compared with 13,000-B.t.u. coal at $3.00 per ton.

The Baltimore & Ohio Railroad has donated to the Industrial Commission of Ohio a steel car to be used in demonstrating modern safety devices. The car will be equipped early in September by various manufacturing companies, as well as by the Commission, with models of safety devices and exhibits illustrating proper sanitation and ventilation. It will be sent into the yards of industrial plants throughout the state, so that employers and workmen may inspect the exhibits. The Commission is also preparing a motion picture film showing the working of the compensation law in Ohio, and particularly the causes of accidents as reported by the Commission.

The power required in rolling rectangular steel sections (*i.e.*, that expended in deforming the heated metal) may be approximately calculated from Victor E. Edwards' formula: Horsepower $= [C\,W \log(A_1/A_2)\sqrt{(D/T)}]/t$, in which W = weight of ingot, lb.; $A_1(A_2)$ = sectional area of ingot before (after) the pass, sq. in.; D = diameter of rolls at the pass in question, in.; T = thickness of ingot when leaving rolls, in.; t = duration of pass, sec. For preliminary calculations, assuming an initial rolling temperature around 2200 deg. fahr., the coefficient C may be taken as 12, a mean value determined by the author from the data of an elaborate series carried out in Germany some years ago by Dr. Ing. J. Puppe.—C. M. Sames, in *The Iron Age*, June 1, 1916.

The advantages of pulverized coal in locomotive practice are summarized by the committee of the International Railway Fuel Association in charge of the subject as follows: (1) Smokeless, sparkless, and cinderless operation; (2) maintenance of maximum boiler pressure within a uniform average variation of 3 lb. without popping; (3) an increase of from 7.5 to 15 per cent in boiler efficiency as compared with burning lump coal on grates; (4) saving of from 15 to 30 per cent in fuel of equivalent heat value fired; (5) enlarged exhaust-nozzle area, resulting in greater drawbar pull and smoother working of locomotive; (6) elimination of ashpit delays, facilities and expense, and reduction of time required for, and ease in, firing up; (7) maintenance of a relatively high degree of superheated steam; (8) no accumulation of cinders, soot or ashes in boiler flues, smoke box or on superheater elements; (9) no punishment or overheating of fire box, sheets, etc.; (10) elimination of arduous manual labor for building, cleaning and dumping fires; (11) avoidance of expense and annoyance of providing various sizes and kinds of fuel; (12) elimination of necessity of front-end and ash-pan inspection, and for special fuels, firing tools and appliances for building, stoking and cleaning fires; (13) equal provision with engineer for fireman to observe signals and track, thus reducing the liability of accident.

The economical production of power from coke-oven gas is discussed by G. Dearle in a recent paper before The Institution of Electrical Engineers. In collieries where a proportion of the output of coal is converted into coke in either waste-heat or regenerative ovens, there is always a certain surplus volume of gas of high calorific value which is available for the production of power. In the case of the regenerative type of coke oven, the volume of gas thus available is much greater than in the older pattern of waste-heat oven, and it is partly for this reason that the majority of new coke-oven installations during the past few years have been of the regenerative type.

The advantage of regenerative ovens is that the whole of the surplus heat in the coal is produced in the form of a combustible gas instead of merely as a waste-heat product. This combustible gas can be used to much greater advantage than the waste-heat product, for by utilizing it in gas engines it is possible to develop 3 to 4 times the power that can be obtained from the use of waste heat under boilers. There is also an advantage in being able to convey the gas any distance without deterioration, which is not possible in the case of the waste heat where the boilers must be installed quite close to the coke ovens.

The particular installation under review forms the power plant for a colliery, and consists of three 500 b.h.p. vertical tandem single acting gas engines operating on the Otto or 4-cycle principle. Further engine details are given and reference is made to ignition, lubrication, cooling and ventilation.

CORRESPONDENCE

CONTRIBUTIONS to the Correspondence Departments of The Journal by members are solicited by the Publication Committee. Contributions particularly welcomed are suggestions on Society Affairs, discussions of papers published in The Journal or brief articles of current interest to the membership.

PREPAREDNESS AND DOMESTIC NITRATE

To the Editor:

In the recent discussion[1] of the methods of organizing our industries in preparation for a possible war, a short reference was made to the necessity for a domestic supply of nitrogen in a form available both for plant life and convertible to war munition purposes in case of a conflict.

There has been recently considerable publicity given to the fixation of atmospheric nitrogen. The proposals along this line have been somewhat spectacular, and it is perhaps well to sound a note of warning in this matter lest there be a tendency to exaggerate the necessity of developing huge supplies of water power purely for the production of nitric acid. A very timely word is given in an article appearing in the July issue of the *Journal of Industrial and Engineering Chemistry*, by J. W. Turrentine, of the United States Bureau of Soils. In this article the writer calls attention to the possibilities of obtaining an independent nitrate supply from the bituminous fuel resources of this country.

The process of producing coke with the recovery of by-products in the form of tar and ammonia, as well as a certain quantity of gas, is well known and widely practised in this country, and the ammonia supply from this source represents a very considerable factor in the present fertilizer situation. The great bulk of ammonia thus produced is in the form of ammonium sulphate, which is directly available as a fertilizer. It is not so well recognized that all the ammonia thus produced is directly available as a raw material for nitric acid production.

The catalytic oxidation of coal gas ammonia to nitric acid is being commercially operated in Germany, and had been commercially operated there for a period of at least five years preceding the start of the war. There is no problem in connection with the oxidation of this coal ammonia which has not been solved on a commercial scale in at least one large plant in Germany.

It may be taken for granted, therefore, that the ammonia generated from our bituminous coals is directly available in time of war for the production of huge quantities of nitric acid. The only thing lacking is that this process should be introduced on a commercial scale in this country so that it may be thoroughly understood in its practical full-scale application. By this means we would put ourselves in position to take immediate advantage of our domestic ammonia supply as a source of nitric acid in case the Chile nitrates should be cut off.

The second problem in connection with such means of nitric acid production lies in providing a more flexible source of ammonia from the coal. The great point raised against the by-product coke ammonia has been its almost complete dependence on the major product, coke. The heavy first cost of a by-product coke plant, the amount of time needed to build and put these plants in operation, and the necessity of providing some immediate use and market for the main coke product have all been urged against this source of nitrate supply.

The writer also calls attention to a further objection to this method of ammonia production, which is that the amount of available nitrogen recovered from the fuel is little more than 15 per cent. This means that 85 per cent of the theoretical possible ammonia in the fuel is being lost in the coking process. There is, however, a process of treating bituminous fuel known as the by-product producer gas system, by which not 15 but 70 per cent of the available nitrogen in the fuels is converted into ammonia in such way that the products of the plant consist of a useful fuel gas, ammonia and tar only. The first cost of a plant capable of producing fuel gas and ammonia in this manner is very much less than the first cost of an equal coal capacity by-product coke oven, and the fuel gas which is the main product of the producer plant is entirely suitable for almost all industrial operations requiring heat application, as well as in gas engines or as fuel for a modern steam turbine plant in the production of power. These plants, therefore, may be expanded rapidly in time of trouble and without limit, being independent of the narrow field of coke requirements. They would produce not less than four times the amount of valuable ammonia per ton of fuel that is recovered from a corresponding by-product coke plant.

The by-product producer gas industry is well known in Europe and has been thoroughly developed. Its introduction in this country is lagging behind European practice mainly for the very reasons which caused the early neglect of the by-product coke oven system, that is, a lack of intelligent adaption of the process to our local fuels and conditions. It is of interest, however, to note that in the last two years some very successful development work has been undertaken in this country looking toward the economic adaption of the by-product producer system to American conditions. It would seem, therefore, that full consideration should be given to this process as a means of providing a domestic nitrate supply.

Lewis A. Riley, 2d.

New York, N. Y.

[1] Industrial Preparedness, The Journal, June, 1916, p. 435.

DISCUSSION OF TURBINE TESTS

To the Editor:

Although not a member of The Am. Soc. M. E., I submit the following as a discussion of the paper by H. G. Stott and W. S. Finlay, Jr., on Report upon Efficiency Tests of a 30,000-kw. Cross-Compound Steam Turbine which appeared in the June issue of The Journal.

A notable and admirable feature of the paper is the summary of the turbine test results uncorrected to standard conditions, Table 2. The correction curves for pressure variation, superheat-variation and vacuum variation, Figs. 12, 13 and 14, which are used to calculate the last three columns of Table 2, the figures of which are in turn plotted as Figs. 7, 8 and 9, raise the question as to the foundation upon which the correction curves rest. If the writer is not much mistaken they do not rest upon experimentation with the turbine to the test

results of which they have been applied, nor upon any similar turbine. This point is not brought up in the paper, but the writer believes it to be of considerable importance. The turbine characteristics after correction by these curves displayed features unexpected either by the manufacturer or the purchaser; and therefore probably, had it been possible to determine the real correction curves from the turbine itself or from a turbine of similar size and design, the final turbine characteristics referred to standard conditions would have displayed features not exactly like those shown in Figs. 7, 8 and 9.

That apparently no attempt was made to establish the precise characteristics of the turbine from the actual tests data appears to the writer somewhat unfortunate, because by the conditions of the tests the variation of pressure, superheat, and vacuum from the contract conditions were very considerable, and it is such considerable variation from constant conditions of pressure, superheat, and vacuum which it is essential that actual test results should show if the inherent performance of the turbine with varying initial and final steam conditions is to be determined by the turbine itself; thereby determining of course the performance of the machine under the definite contract conditions.

That is, every turbine obeys an individual law, all quantities establishing its performance being bound together in a definite relationship. Of these quantities there are five, namely, the power generated (measured electrically, thus including the generator efficiency); the rate of steam flow; the initial pressure; the initial superheat; and the terminal pressure, that is, the vacuum. It is these five quantities which are ordinarily made use of, more or less arbitrary relationships between the ratio of the rate of steam flow and the power generated (that is, the economy) and the initial and final conditions being applied, and then the resulting figures of weight of steam flow and power generated being plotted and recorded as the performance of the machine under rated conditions.

It need hardly be said that this procedure is inaccurate and unnecessary, if only, by analysis of actual results under varying conditions (such as are tabulated in all but the last three columns of Table 2), the relationship which binds together the five quantities named above may be discovered. I would commend to those interested the paper of Edgar Buckingham on the forms of empirical equations read before the Society in 1915.[1] In his paper problems of just this sort and apparently not more difficult than the one here discussed are handled by a method of great power.

With reference to the important matter of the queer results and effects produced by the separator between the high- and low-pressure cylinders, both before and after removal of the internal baffles, mentioned in the paper and elaborated in the oral discussion, it is the writer's opinion that a good deal is to be explained by the probable simultaneous action of the separator as a separator and as a superheater. The basis for this opinion is the writer's experience in testing steam turbines of various detailed designs and rated capacity ranges from 7,500 kw. to 20,000 kw., in which it has invariably been proven that superheating of the exhaust steam occurs when sudden transformation of energy from kinetic form is occasioned by the blast of exhaust steam striking on the top row of condenser tubes. This superheating, under the ordinary range of high vacuum and load variation, has had the magnitude of anywhere between one and four deg. fahr. superheat. It seems obvious that with steam of very much higher initial pressure, and therefore higher density, entering the separator and caused to pursue a tortuous course by the baffles, ample opportunity exists for similar superheating. Such superheating would naturally vary decidedly with the rate of steam flow and the entrance pressure. Simultaneous separation of moisture and superheating of steam would occur.

It is not improbable that this unlooked-for phenomenon was at least a partial cause of the unexpected hump in the economy curve between 22,000 kw. and 27,000 kw.

The writer regards as still more remarkable, as did some of those taking part in the oral discussion, the dip in the economy curve between 30,000 and the maximum load which the machine could carry, approximately 33,000 kw. He confesses to having remained unenlightened by the oral discussion given this point. It is of course possible that here again the variation of the relative moisture separation and superheating in the separator with varying rate of steam flow and entrance pressure may have played a part.

H. L. H. SMITH.

Brooklyn, N. Y.

[1] THE JOURNAL, September, 1915, p. 531.

TO THE EDITOR:

I note in connection with Table 2, sixth column from the right-hand end of the paper by H. G. Stott and W. S. Finlay, Jr., on Report upon Efficiency Tests of a 30,000-kw. Cross-Compound Steam Turbine which appeared in the June issue of The Journal, that the temperature is given for the 30-in. barometer (presumably that of the mercury) as 58.1 deg. fahr.

Some years ago, in preparing a book of Steam Tables for Condenser Work I had occasion to calculate the temperature of the mercury for 30-in. mean atmospheric pressure barometer and found that this was 58.4.

As it had usually been assumed that the temperature for a 30-in. barometer was 62 deg., this being also the temperature at which the standard English yard is maintained, the figures leading to the temperature of 58.4 were carefully checked and are given below.

On the basis of experiments by Scheel, a deg. fahr. change in the temperature of a column of mercury confined in a tube changes its height 0.000101 times. If the height is increased from 29.92 to 30 in. the mean height is 29.96 and the mean change for each degree rise in temperature is $29.96 \times 0.000101 = 0.003026$ in. The increase from 29.92 to 30 in. is 0.08 in., which, divided by 0.003026, equals 26.4 deg. fahr. Adding this to the 32 deg., the temperature for the 29.92-in. barometer, we have $32 + 26.4 = 58.4$ deg. fahr. as the temperature for a 30-in. barometer.

I would be interested to know what figures were used in arriving at the temperature of 58.1 deg.

PAUL A. BANCEL.

New York, N. Y.

HAND-FIRED BOILER SETTINGS

TO THE EDITOR:

So far as hand-firing is concerned, Mr. Monnett's paper published in the August issue of The Journal illustrates in an interesting way the development of settings to reduce smoke. The principles involved may be shown to underlie the construction of practically all stoker settings as well. The author of the paper mentions these principles in a somewhat parenthetical way, as (1) high temperature; (2) auxiliary air supply; (3) mixture of gases. Many engineers would eliminate the second of these principles. Air jets introduced back of the main grate, more especially if steam is used to supply the air, are apt to have a chilling effect, and in the hands of a

careless operator may lead to serious impairment of boiler efficiency. Steam jets have frequently been regarded with suspicion, the smoke abatement which they are pretty certain to produce being mainly the result of smoke dilution. I think Mr. Monnett's supplementary air jets are profitable because he runs with a heavy fuel bed, and that with a fire of normal thickness the proper place to introduce all of the air is under the grates, so that it will get the maximum amount of warming before it begins to combine with gases from the fuel. Supplementary air, heated in passages through the walls of the setting, is a delusion, because the heating is inadequate and the passages cannot be kept clear.

As a substitute for the second principle offered in the paper, some operators would suggest *room for the flame*. A suitable distance must be traversed before the flame is allowed to strike a relatively cold surface (such as the shell of the boiler). Anyone can verify the necessity for this by the old experiment with a candle flame and a saucer. In Figs. 1 to 3 of the paper this distance is provided. In Figs. 4 and 5 it is not, and the supplementary air supply is introduced as a device for transferring combustion from the grate, where it belongs, to the region behind the bridge wall. Just how much room should be provided for the flame is not known. Twelve feet is sometimes suggested, but few stokers even attempt this. Undoubtedly the desirable amount of space depends upon the nature of the coal, the thickness of fuel bed, the rate of combustion and temperature relations. This is the most important factor in smokelessness, next to thorough mixture of air and gases, because it implies the third principle, of a maintained high temperature.

W. D. ENNIS.

Brooklyn, N. Y.

DYNAMIC BALANCE

TO THE EDITOR:

In the discussion of Mr. Akimoff's paper on Dynamic Balance, published in the August issue of The Journal, I note that Mr. Hodgkinson speaks of the difficulty of balancing heavy bodies by rolling the axles on level hardened surfaces because the journals sink into the ways to a slight degree so that "extreme sensitiveness cannot be obtained because of the field having to run uphill." It is true, of course, that this deformation of the axle or shaft, and of the hardened straight edges, adds to the resistance of rotation, but it does not seem to me to be true that the field runs uphill. If the deformation of the shaft and of the straight edges is uniform, the path of the axis of the rotating body will be parallel to the straight edges, and if they are level this path will also be level, and there will be no running uphill.

Assuming that the deformation of the shaft and of the straight edge gives a bearing surface of considerable magnitude, say for instance $\frac{1}{4}$ in. in width, then the metal for $\frac{1}{8}$ in. in advance of a vertical line drawn from the center of the axis is being compressed by the rolling axle. But so long as this compression is within the elastic limit of the materials, the energy consumed in this deformation ahead of the vertical line referred to is restored to the rolling axle by the recovery of form in that part of the depressed surface which is behind the vertical line drawn from the center of the axis; and the only loss of energy is in the internal resistance of the materials themselves, which, in the case of hardened steel deformed well within its elastic limit, is very small.

Probably the main cause of the impression that heavy bodies have considerable frictional resistance to rotation under such conditions is that relatively large forces are required to set them in motion, or to accelerate them, independently of friction.

Mr. Hodgkinson speaks also of the fact that the film of oil in the bearing of a heavy armature will be squeezed out within a short time, so that there will be metallic contact and a considerable increase of friction. In 1897 I first saw in a municipal electric light station in Manchester, England, bearings of direct-connected generators which were fitted with oil channels and force pumps so that oil was driven under the journals at the center of the bearings, flowing out around the journal at the ends in a thin stream and literally supporting the journals upon this maintained film.

I do not know to what extent this plan has been adopted elsewhere, but whether there are sufficient reasons for its general adoption or not, it would remove the difficulty referred to by Mr. Hodgkinson.

FRED J. MILLER.

New York, N. Y.

REPLY TO COMMENTS ON RECLAMATION PLANT

TO THE EDITOR:

Answering Mr. W. B. Gregory's comments, appearing on page 561 of the July issue, on my paper entitled Design and Test of a Large Reclamation Plant, published in the May issue, I would state that in the particular plant under consideration, the average pumping head has been estimated to be approximately 16 ft.; and that during the normal operation of the plant, only three units would be running, one on each discharge pipe. Conditions of rainfall and run-off would be such that the occasion for operating more than three units would be comparatively rare. Therefore the design of discharge pipes has been governed to some extent by the normal operation—in other words, the conditions of operation which call for the greatest expenditure of power for pumping purposes. Further, the diameter of the discharge pipes is governed by the relation between the power cost and construction cost. The writer's calculations in this particular case showed that the most economical annual cost, including operating and depreciation interest charges, was obtained with pipes approximately 78 in. in diameter.

During the winter months, when this plant will be in operation, the suction pipes will be under water. In Fig. 8 of the paper, the water outside of the levee is at the end of a very dry season, and at a normal low period. It might be said that at no time during the ordinary course of operation of the plant will the suction pipes be exposed, as shown by this illustration, therefore the discharge pipes may be said to have a complete water seal.

In reference to advantages and disadvantages of carrying pipes through or over the levees, this question was gone into rather carefully, and it was decided to carry the pipes through the levee, primarily on account of construction difficulties. At the time the plant was installed, the levees at this point were not completed, therefore pipes were very easily carried through levees and supported on firm ground. To carry pipes over levees would have meant considerable trestle work and would interfere seriously with the building of levees, particularly with additions to levees, which are necessary as time goes on, on account of wasting away due to action of the elements and other causes.

The installation of gate valves on the discharge pipes was not governed by whether pipes went through or over levees. The valves were installed for two reasons: *First*, to reduce priming

difficulties on account of the extremely large volume of discharge pipes, and *second,* as a safety factor in case of breakage of pumps, etc., which might cause serious flooding before sluice gates and check valves could operate on the extreme end of discharge pipes.

G. C. NOBLE.

San Francisco, Cal.

THE INDUSTRIAL SERVICE MOVEMENT

TO THE EDITOR:

The paper entitled Industrial Service Work in Engineering Schools, read by Prof. J. W. Roe, of Yale University, at the June, 1914, meeting of the Society, created a great deal of interest. Among other things Professor Roe said:

"While thousands have been invested in welfare enterprises, we know that the purpose behind them is being accomplished in scores of industrial organizations, without any special equipment, by the personal influence of some man or men in charge. These men seem to have a genius for understanding and developing the best in the men under them. They have no fixed rule or system. It is a question of attitude and personality. They create an atmosphere of confidence instead of suspicion and distrust. Their influence permeates a whole factory, kindling ambition and developing better workmen and better industrial conditions. Such men can accomplish wonders without welfare equipment. Given a welfare they make it successful and beneficial to all. Their value to the employer, to the workman, and to the community can hardly be overestimated; the new art of management under the direction of such men as these will prove a permanent success. The development of just such men as these is the aim of the Industrial Service Movement."

Members of the Society will be interested in some of the most recent developments in this Industrial Service Movement, and in some of the latest statistics of its growth. At present over 4000 students from upwards of 250 colleges and technical schools are engaged in many forms of volunteer service for 100,000 working men and boys. Their service is surprisingly conscientious and efficient. Nevertheless the college students probably get more than they give, which is part of the game.

The Industrial Department of the International Committee of Young Men's Christian Associations now has on its mailing list several thousand engineering graduates, who became interested in their undergraduate days. These men are followed up and kept in touch with as far as possible. Remarkable letters are frequently received from many parts of the continent. The quotations below are characteristic:

"I had already read of this Movement in the technical journals, and it seems to me to be one of the most admirable and needed advances made in the industrial field for years. I want to be of every possible service to you."

"I have always intended to take an active part in this work as soon as I should settle down, for the little I did in college in that line has left me with a sense of personal responsibility to continue work. I am writing to you now to let you know that you can count on me to do my utmost to help the good cause along."

"I am glad to state that I think the industrial work is of very great permanent benefit to those who take active part in it. I am sure that by giving English lessons to Italian laborers I learned more of them than I could have learned in any other way."

"I have come to realize to much greater extent than ever before the importance and even necessity of this work in the routine of the undergraduate, especially the one who intends going into such lines as I have taken up."

"Although I never did any of this work in college, I heard various men speak of it and resolved to undertake it after graduation. I have now charge of all the foreign employees in this plant and have always tried to treat them on the square. Before I came, a cursing, brutal foreman made all sorts of labor difficulties. Since I took hold there has been no trouble whatever and the men have remained absolutely loyal. Am now starting special classes for our men in rooms provided by our company. I am teaching one of the classes myself and enjoy it hugely."

"I now have charge of all the accident prevention work in our factory and feel sure that I would not be holding this position today were it not for the sympathetic touch with the work which I got in my undergraduate days. I consider the Industrial Service Movement one of the greatest influences for industrial righteousness in the country today."

One of the most interesting illustrations of how much can be accomplished by the young engineer is afforded by a Michigan man who graduated in 1913. Because of his touch with the Movement in his senior year, he showed a remarkable interest in the foreign men in his company. Officials noted his ability, placed him in partial charge of all their educational work for foreigners, with the result that over a thousand employees in that company study English and American citizenship. They are taught by sixty volunteer leaders in sixteen different class rooms provided by the company.

Why confine the advantages of this Movement to these engineering students who can find time to teach a class of foreigners, lead a club of apprentices, talk in labor unions or engage in some other form of definite service? It is manifestly impossible to get every student to do such work. But *it is possible to help every engineering student in a college to realize his opportunities and social responsibilities, and to get some conception at least of the human side of his job.* To this end it is encouraging to note the increasing tendency to include such instruction in the engineering curriculum. Probably the most recent suggestion in this regard is a proposed required course for seniors, a rough outline of which is given below.

This outline has been prepared by request with the help of some leading engineering professors and business men. It is arranged to cover 32 or 64 class periods—four months' or eight months' work at the rate of two periods a week. This is merely a rough preliminary outline. The course should be supplemented by engineering trips to study certain industrial conditions and the betterment work of selected companies and social agencies.

1 *Introductory—The Human Factor in Industry*
Two periods. Showing in an interesting way that men comprise the most important element in any industrial operation. Do we realize that one of the greatest elements of success is the ability to deal intelligently with men?

2 *Historical—The Evolution of the Individual Worker in Industry*
From two to four periods—Industrial Evolution.

3 *Industrial Organization—The Influence of the Modern Factory System on the Worker*
Three to five periods. General and departmental organization. Management. The relation of wages, hours, etc. The interdependence of men.

4 *Human Factors in Production*
From six to sixteen periods. Problems to be solved.
a General—Capital and Labor, immigration, unionism, etc. What shall our attitude be toward these great questions?
b Working Conditions. Do right conditions pay?
c Living Conditions. What relation has health to efficiency?

d Leisure Conditions. Why is "big business" interested in these things?

5 *Vocational Guidance and the Education of Employees*
Two to four periods. To what extent does improving a man's education increase his efficiency?

6 *Coöperative Organizations*
Two to four periods. National Civic Federation, National Council for Safety, Russell Sage Foundation, the Y. M. C. A., etc.

7 *Legislation and Public Opinion on Industrial Questions*
Two to four periods. To what extent have welfare requirements been incorporated in Federal and State Laws? To what extent is public opinion a determining factor?

8 *The Programs of Typical Companies. Industrial Betterment*
What has been and can be done along such lines as indicated above?

9 *Scientific Management*
Principles, importance of motion study, time study, division of labor, etc. Human aspects of the system.

10 *How to Handle Men*
Examples of industrial leaders who have been successful in handling men. The Industrial Service idea.

11 *Conclusion—The Engineer's Responsibility for Service*
In the light of the above what will be your attitude as you graduate? Will your life purpose be wealth regardless of others, or service for others?

This is merely a suggested outline and is being constantly improved. Most of the sub-topics and comments have been omitted through lack of space. Where it is not thought possible to give such a course, special lectures on kindred subjects help greatly. Weekly discussion groups on industrial problems are often planned. A special reference library on industrial service, frequent articles in college periodicals, *discussions of the work at meetings of the student engineering societies*, all help maintain interest.

After spending six years promoting this Movement in scores of colleges, the writer is convinced that it is destined to a great future. The response grows every week. In a recent trip of six weeks through the Universities of the Middle West over 1500 students indicated their interest, and over 600 volunteered for definite service. Men are not pushed into this work. It is placed squarely before them and they can do as they please. Yet the universal experience is that the best and "biggest" men in college find time to help.

The interest and coöperation of the National Engineering Societies is of tremendous value, and I bespeak the continued and increasing support of The American Society of Mechanical Engineers.

FRED H. RINDGE, JR.

New York, N. Y.

HIGH-TEMPERATURE INSULATION

TO THE EDITOR:

While inaccuracies in the introductory generalizations of the paper by Mr. Boeck in the August issue of The Journal do not lessen the importance and accuracy of the main body of his article, it is none the less unfortunate that this introduction contains such statements.

It is true that "heat is a form of energy consisting of molecular vibrations," but it is not true that it is "subject to the general laws of wave motion." It can not "be reflected, refracted and dispersed by creating the proper conditions." While the introduction of layers of material of low heat-transmitting value decreases heat flow, the use of alternating layers is not necessary, because the resistance to flow of heat in such cases is not due to "breaking up or changing the wave length."

It is inaccurate to speak of heat as being radiated. Heat cannot be radiated. Hot bodies do emit radiant energy, which is, however, not heat, but vibrational energy of the luminiferous ether. This energy can be transmitted not only, as Mr. Boeck states, through the gaseous state of matter, but also through liquids and many solids, such as glass, silica and the like. In the opinion of the writer, some of the phraseology in the introduction of this paper produces loose and inaccurate thinking, and renders infinitely more difficult the application of scientific knowledge to the solution of industrial problems.

On the other hand, the value of Mr. Boeck's contribution in calling the attention of the engineering profession to a material of high resistance to heat flow, yet possessing at the same time satisfactory mechanical qualities, especially reasonable mechanical strength and resistance to vibration and to the contraction and expansion caused by temperature change, must not be underestimated. Furthermore, the emphasis laid upon the fact that air spaces at high temperature are better conductors of heat than even relatively poor solid insulators, owing to the high radiation losses across the gaseous spaces at high temperature, is well worth while. This fact, though long known, is not even yet appreciated to the extent that it should be. Owing to the high heat conductivity of firebrick, and even of common brick, the construction of a fire wall of high heat resistivity is difficult, and indeed impossible, without the use of some such insulating material as that described by Mr. Boeck.

It would be of very real value if Mr. Boeck would state whether the heat loss diagrams of Fig. 7 are diagrammatic, or represent experimental results. In the latter case, a statement of the experimental method employed is important, because the accuracy and reliability of the methods hitherto employed are unsatisfactory; and if carefully conducted experiments of this sort were reported in detail, they would not only furnish the heat conductivity of the specific material tested, but also add to our knowledge of the best methods of testing such substances intended for technical insulation.

W. K. LEWIS.

Boston, Mass.

There were nearly 33,000 students in the engineering schools of the United States in 1915, divided among the various branches as follows: Mechanical, 7751; civil, 7182; electrical, 6637; general, 6059; chemical, 2383; mining, 1922; other, 958.

The U. S. Bureau of Standards has made tests of unusually large wire ropes intended for the Panama Canal. These ropes, of plow steel, showed an ultimate strength, in lb. per sq. in. of net area, of 184,200 for the 2-in. rope and 214,900 for the 2¾ in., while the total ultimate loads ranged between 304,000 lb. for the 2-in. rope and 866,000 lb. for the 3¼ in.; a specimen of the last named diameter Monitor plow steel showed 937,000 lb.

The tests were made on the Emery machine at Washington, and special holders were designed for it by the Bureau. The capacity of this machine is 1,200,000 lb. and the special holders were provided in order that this full tension might be utilized.

WORK OF THE BOILER CODE COMMITTEE

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 39th St., New York City.

Since the publication of the April issue of The Journal, in which interpretations of Cases Nos. 45-58 inclusive were presented, three meetings of the Boiler Code Committee have been held: one in March, at which Cases Nos. 59-60 and 63-66 were taken up, Cases Nos. 61-62 being left in the hands of the Committee; one in May, when Cases No. 68, Nos. 70-73 and Nos. 75-80 were considered, Cases Nos. 67, 69 and 74 being left in the hands of the Committee; and one in June, at which interpretations were rendered in Cases Nos. 49*a*, 61, 67, 69, 74, and 84-88, Cases Nos. 81-83 having been annulled and Case No. 87 left in the hands of the Committee. Thus, a total of 26 interpretations have been rendered, three cases having been annulled, leaving two Cases and Case No. 49*b* still in the hands of the Committee.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society for approval, after which it is issued to the inquirer and simultaneously published in The Journal, in order that anyone interested may readily secure the latest information concerning the interpretations.

Below are given the interpretations of the Committee, as approved by the Council on July 27, 1916, in Cases Nos. 49*a* and 59-88 inclusive. In this report, as previously, the names of inquirers have been omitted.

Case No. 49

Inquiry: a. How far does the Boiler Code apply to the case of flash type boilers, or those having a forced circulation with no fixed steam and water line?

Reply: a. The material for boilers of this class shall conform to the requirements of the Code. All other requirements shall also be met except where they relate to special features of construction made necessary in boilers of this type, and to accessories that are manifestly not needed or used in connection with such boilers, such as water gages, water columns and gage cocks.

Inquiry and Reply: b. (In the hands of the Committee.)

Case No. 59

Inquiry: Is it within the requirements of the Boiler Code to use flange steel for parts of boilers where fire-box steel is required, provided the steel has all the physical and chemical requirements of the fire-box grade. The condition of the iron and steel market is such that the manufacturers must resort to extreme means to obtain the material.

Reply: If the plate manufacturers will guarantee the steel is up to that of the specifications for fire-box steel, it is obvious that they, the steel manufacturers, may restamp for you the plate in question. The Code requires that no plates shall be used as fire-box steel unless so stamped by the steel manufacturer.

Case No. 60

Inquiry: Is Par. 199 applicable to the stay-bolting of water legs in water tube boilers of the Heine type? We understand it is the practice of some manufacturers to calculate this construction under Par. 206. Please give an interpretation of Par. 207 also.

Reply: Your staybolt spacing would rightly come under Par. 206. The construction of handhole openings, etc., must be such that the requirements of Par. 207 are complied with.

In applying Par. 207, the plate with handhole openings must be considered as a continuous beam supported at the center lines of stays for which there are standard engineering formulae.

Case No. 61

Inquiry: Can flanges for blow-off piping be drilled for six bolts on a 6 1/16-in. bolt circle for the 2½-in. pipe size, whereas Table 16 of the Boiler Code requires four bolts on a 5⅞-in. bolt circle?

Reply: Par. 299 of the Code refers to the flanges on the discharge sides of steam nozzles, or to flanges, when used, left by the manufacturer as a part of the boiler for the connection of other piping or fittings, and to fittings shown on page 112 for pressures up to and including 250 lb., and does not apply to fittings specially designed as part of the boiler. Where threaded openings are left on the boiler, Par. 268 shall apply.

Case No. 62

(In the hands of the Committee.)

Case No. 63

Inquiry: Are we to understand that iron through-bolts not welded will be allowed 8500 lb. per sq. in. under Table 4? Par. 4 specifies that welded braces should be of iron.

Reply: Stresses given in Table 4 cover both iron and steel stays, either of which may be used. According to Par. 4, if stays or braces are welded, they must be made of iron.

Case No. 64

Inquiry: Interpretation is requested relative to the value of the constant in the formula of Par. 199 when applied to vertical tubular boilers in which the furnace sheet is thicker than the outer barrel sheet. If the furnace sheet is of such thickness as to permit of using 120 for C in the above mentioned formula, and the outer barrel sheet to which the furnace sheet is stayed is of such thickness as to permit of a value of 112 for C, which constant should be used?

Reply: When two sheets are connected by stays and but one of these sheets requires staying, the value of C, in rule 199, is governed by the thickness of the sheet requiring staying. When both sheets require staying as flat surfaces, the value of C is governed by the thickness of the thinner sheet.

Case No. 65

Inquiry: A definition is requested of the word "fitting," as to whether it refers, in connection with Par. 299, to ells, tees, crosses, and the other ordinary pipe fittings, or whether it may be extended to cover such irregular shapes as water columns, blowoff connections, valve bonnets, etc.

Reply: Par. 299 refers to the flanges on the discharge sides of steam nozzles or to flanges, when used, left by the manufacturer as a part of the boiler for the connection of other piping or fittings, and to fittings shown on page 112 for pressures up to and including 250 lb., and does not apply to fittings spe-

cially designed as part of the boiler. Where threaded openings are left on the boiler Par. 268 shall apply.

CASE NO. 66

Inquiry: Par. 270 is ambiguous in that one clause of the Paragraph specifies a maximum rise of pressure of 6 per cent above the highest pressure to which the valve is set, while the other specifies a maximum of 9 per cent above the allowable working pressure. An interpretation is also requested of what is intended in Par. 292, page 75, respecting water glass connections.

Reply: Par. 270, page 68 of the Code, is intended to specify a safety valve capacity such that the safety valve or valves will discharge all the steam that can be generated by the boiler without allowing the pressure in any case to rise more than 6 per cent above the maximum allowable working pressure, and there is no rule in the Code which warrants a rise in pressure of more than this for any safety valve setting. Where a safety valve or valves are set at a pressure considerably lower than the maximum allowable working pressure this rule alone would not be sufficient, as it would allow the pressure in a boiler built for 100 lb. to increase to 106 lb. with a low pressure safety valve on the boiler set at, say, 5 lb. In order to cover this feature, the further condition was imposed that the discharge capacity must be such that the pressure will not rise more than 6 per cent above the highest pressure to which any valve is set.

An interpretation of what is intended in a reply to an inquiry in regard to Par. 292, page 75, respecting water glass connections, is published in the January 1916 issue of The Journal under Case No. 35.

CASE NO. 67

Inquiry: Is there not a conflict between Pars. 253 and 223 of the Boiler Code as to the punching of rivet holes full size? Par. 253 makes exception as regards rivet holes for attaching stays or angles to heads, inferentially permitting such rivet holes to be punched full size.

Reply: Par. 253 excepts rivet holes for attaching stays or angle bars because such parts need not be bolted in position when drilled.

Par. 223 requires that all rivet holes in the parts to be braced, as well as in the brace itself, must be either drilled full size, or punched under size and drilled. (See Case No. 27).

CASE NO. 68

Inquiry: What is the application of Par. 186 to unfired vessels subjected to pressure, whether steam, water or air? Such unfired vessels with joints formed by autogeneous welding are extensively used carrying high pressures.

Reply: The Committee has not formulated rules for pressure vessels other than steam boilers, and is, therefore, not in a position to pass upon this question.

CASE NO. 69

Inquiry: Please explain the application of Par. 223 of the Boiler Code to the design of the ordinary form of diagonal boiler brace.

Reply: In previous cases of this kind (See Case No. 29) the Committee has said that all braces used in A.S.M.E. Code boilers should conform to the Code in every detail. Difficulty has been experienced in interpreting Par. 223, which applies to such braces, and the Committee therefore submits the following to explain how this paragraph should be applied:

> The requirements in Par. 223 are based on the "required cross sectional area of the brace." To apply Par. 223, proceed as follows:
>
> 1. Determine the "required cross sectional area of the brace" by first computing the total load to be carried by the brace, and dividing the total load by the values of stresses for unwelded stays given in Table 4.
>
> 2. Design the body of the brace so that the cross sectional area shall be at least equal to the "required cross sectional area of the brace" for unwelded braces. Where the braces are welded, the cross sectional area at the weld shall be at least as great as that computed for a stress of 6000 lb. per sq. in. (See Table 4.)
>
> 3. Make the area of pins to resist double shear at least three-quarters of the "required cross sectional area of the brace."
>
> 4. Make the combined cross section of the eye at the side of the pin (in crowfoot braces) at least 25 per cent greater than the "required cross sectional area of the brace."
>
> 5. Make the combined cross sectional area of the rivets at each end of the brace at least $1\frac{1}{4}$ times the "required cross sectional area of the brace."
>
> 6. Design each branch of a crowfoot to carry two-thirds the total load on the brace.
>
> 7. Make the net sectional areas through the sides of the crowfeet, tee irons, or similar fastenings at the rivet holes at least equal to the required rivet section, that is, at least equal to $1\frac{1}{4}$ times the "required cross sectional area of the brace."
>
> 8. The cross sectional area through the blade of a diagonal brace where attached to the shell of the boiler shall be at least equal to the required rivet section, that is, at least equal to $1\frac{1}{4}$ times the "required cross sectional area of the brace."

CASE NO. 70

Inquiry: Should the use of a non-return stop valve not be made compulsory on all power boiler delivery connections.

Reply: Suggestions for changes will be considered at a hearing before the Committee, where all interested parties may be heard. It is recommended in the Code that such hearings to consider revisions be held at least once in two years, and the time for the first hearing is now near at hand.

CASE NO. 71

Inquiry: Does Table No. 7 in the Code apply to the thickness of plate used where washout plugs are threaded through the sheet?

Reply: It is the opinion of the Committee that Par. 268, including Table No. 7, is intended to refer to any threaded opening in a boiler, which includes openings for threaded washout plugs.

CASE NO. 72

Inquiry: Is there not a misprint in Par. 21 in specifying standard gages for 4 in. and 5 in. tubes and one gage heavier than standard for 3 in. tubes for maximum allowing working pressures not exceeding 165 lb. per sq. in.

Reply: The table in Par. 21 should read:

Diameters less than $3\frac{1}{4}$ in.....No. 12 B. W. G.
Diameter $3\frac{1}{4}$ in. or over, but less than 4 in..No. 11 B. W. G.
Diameter 4 in. or over, but less than 5 in....No. 10 B. W. G.
Diameter 5 in.....No. 9 B. W. G.

CASE NO. 73

Inquiry: Is the use of extra-heavy bronze composition blow-off valves permissible under Par. 402?

Reply: The question of the use of extra-heavy brass or bronze fittings between boiler and blow-off was not considered at the time the Code was compiled, and it is the sense of the Committee that their use is permissible.

CASE NO. 74

Inquiry: The rules in the Boiler Code for girth seams of horizontal return tubuluar boilers do not appear to provide

sufficient rivet area to draw the plates firmly enough together to avoid the necessity of excessive calking. A ruling is requested on this point.

Reply: Par. 184*a* of the Boiler Code was arranged to provide for proper strength for girth joints in all types of boilers. To cover the point raised, the Committee recommends that girth joints of horizontal return tubular boilers have the shearing strength of the rivets not less than 50 per cent of the full strength of the plate at the joint.

CASE NO. 75

Inquiry: An interpretation is requested of Par. 194. The punctuation is such that it is indefinite as to whether the pressure requirement in the first clause refers to the joint or to the flange only.

Reply: The intent of Par. 194 is that all domes 24 in. or over in diameter shall have butt and double strap longitudinal joints, irrespective of the pressure used.

CASE NO. 76

Inquiry: What net area should be considered in calculating stay bolts with tell-tale holes drilled in their ends; also an opinion is requested whether in determining the load on a bolt, the full pitch dimensions of the area stayed should be used, or whether the area occupied by the bolt itself should be deducted therefrom.

Reply: The question as to the area of a drilled staybolt is answered by Par. 220, which specifies clearly the net cross-sectional area of the stay. The full pitch dimensions of the stays should be employed in determining the load on the bolt and the area occupied by the bolt itself should not be deducted therefrom. The full pitch dimensions should be measured as in Par. 199, in which p, the pitch, is specified as the maximum measured between straight lines passing through the centers of the staybolts.

CASE NO. 77

Inquiry: Should the tensile strength stamped on the plate, or the result of actual test be used in the determination of the percentage of elongation as specified in Par. 28.

Reply: It is the opinion of the Boiler Code Committee that the tensile strength obtained by actual test is to be used in determining the elongation.

CASE NO. 78

Inquiry: An interpretation is requested of the reference in Par. 268 to "methods given in Par. 261," and concerning the application of the reinforcing ring that would seem to be required thereby to the boilers of their construction.

Reply: The proportions called for in Par. 261 refer only to reinforcements as described in Par. 260.

CASE NO. 79

Inquiry: Can a low pressure heating boiler, under Part I, Section II, of the Code, be marked A.S.M.E. Standard if the metallic arc welding process has been used in the construction of headers when stay bolts are placed between parallel surfaces adjacent to the welded edges.

Reply: Inasmuch as it is proposed to provide for the lateral stresses in the headers by means other than the welded edges, the Committee sees no objection to the use of the weld in the manner indicated, and if the boiler is constructed entirely in accordance with the A.S.M.E. Boiler Code, both as regards the boiler itself and the fittings, it can be marked "A.M.S.E. Standard" and as specified in Par. 377; if it does not conform to the Code in every respect, marking it in that way would be evidently a misrepresentation. The use of the symbol is specified for power-boilers only which are constructed in conformity with the Code.

CASE NO. 80

Inquiry: Referring to the prohibition by the Boiler Code of any method of welding of boiler shells except by the forging process, has the Committee investigated methods of welding recently? A great deal of time and effort has been put forth by manufacturers of autogenous welding apparatus and the Committee is requested to give this matter further consideration.

Reply: The Committee has since its inception had under constant observation all sorts of welding of pressure vessels, and has gone as far as to ask some of the welding experts of this country to write papers for the Society to bring out further information regarding this particular process. Suggestions for changes will be considered at a hearing before the Committee, where all interested parties may be heard. The Committee recommended in the Code that hearings to consider revisions be held at least once in two years and the time for the first hearing is now near at hand.

CASES NOS. 81, 82, 83

(Annulled)

CASE NO. 84

Inquiry: Can boiler tubes for use in a porcupine type of boiler, where stub tubes are screwed into furnace sheets, be made of standard wrought iron pipe if the threaded ends are properly designed?

Reply: It is the opinion of the Committee that tubes with properly designed threaded ends with sufficient strength in the thread should be permissible. This necessitates a heavier gage of tubing for a given pressure than where the tubes have expanded ends.

The tubes should in all cases meet the boiler tube specifications, pages 40-42 of the Code.

CASE NO. 85

Inquiry: Is it necessary under Par. 406 of the Boiler Code to place an independent check valve between an injector and the boiler when there is a check valve incorporated in the design of the injector?

Reply: To meet the requirements of Par. 406 of the Boiler Code, it is necessary to place an independent check valve, and valve or cock between the pump or injector and the boiler, and this requirement is not covered by the check valve which is located in the injector.

CASE NO. 86

(In the hands of the Committee.)

CASE NO. 87

(In the hands of the Committee.)

CASE NO. 88

Inquiry: What is the required strap thickness for butt strap joints where the plate thickness used does not coincide with the thicknesses specified in Table 1 of the Boiler Code?

Reply: The thickness of butt straps should be obtained by interpolation of Table 1, page 9, of the Code, using as a minimum thickness the plate which agrees with the interpolated value to the nearest thirty-secondth of an inch.

Society Affairs

Engineering Survey

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THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

ABRIDGED LIST OF OFFICERS AND COMMITTEES[1]

OFFICERS AND COUNCIL, 1916

President

D. S. Jacobus

Past-Presidents

Members of the Council for 1916

Jesse M. Smith
Alex. C. Humphreys
W. F. M. Goss
James Hartness
John A. Brashear

Vice-Presidents

Terms expire December 1916

Henry Hess
George W. Dickie
James E. Sague

Terms expire December 1917

Wm. B. Jackson
J. Sellers Bancroft
Julian Kennedy

Managers

Terms expire December 1916

Arthur M. Greene, Jr.
John Hunter
Elliott H. Whitlock

Terms expire December 1917

Charles T. Main
Spencer Miller
Max Toltz

Terms expire December 1918

John H. Barr
H. de B. Parsons
John A. Stevens

Chairman of Finance Committee

Robert M. Dixon

Treasurer

William H. Wiley

Honorary Secretary

Frederick R. Hutton

Secretary

Calvin W. Rice

Executive Committee of the Council

D. S. Jacobus, *Chairman*
John H. Barr
Arthur M. Greene, Jr.
Henry Hess
Spencer Miller
James E. Sague

COMMITTEES, ETC.

STANDING COMMITTEES

Chairmen

Finance, Robert M. Dixon
Meetings, H. L. Gantt
Publication, Irving E. Moultrop
Membership, Henry C. Meyer, Jr.
Library, John W. Lieb
House, William N. Dickinson
Research, R. J. S. Pigott
Public Relations (not appointed)
Constitution and By-Laws, Jesse M. Smith
Standardization, Henry Hess

SOCIETY REPRESENTATION

American Association Advancement of Science
American Society for Testing Materials, Modification Briggs Standard for Pipe Threads
Classification of Technical Literature
Conference Committee on Electrical Engineering Standards
Conference Committee of National Engineering Societies
Conference Committee to Determine Cost of Electric Power
Conservation
Electrical Engineering Standards
Engineer Reserve Corps
Engineering Foundation
Expert Testimony Committee
John Fritz Medal, Board of Award
Joseph A. Holmes Memorial
Naval Consulting Board of the United States
Standardization of Pipe and Pipe Fittings for Fire Protection
Trustees United Engineering Society

SPECIAL COMMITTEES

Chairmen

Administration, Robert M. Dixon
Am. Soc. M. E. Junior Prizes, Robert H. Fernald
Am. Soc. M. E. Student Prizes, Frederick R. Hutton
Boiler Code Committee, John A. Stevens
Engineering Education
Filter Standardization, George W. Fuller
Increase of Membership, Irving E. Moultrop
Metric System
Nominating Committee, Walter B. Snow
Patent Laws
Pipe Threads International Standard, Edwin M. Herr
Power Tests, Geo. H. Barrus
Refrigeration, D. S. Jacobus
Research Committee, R. J. S. Pigott
- Sub-Committee on Bearing Metals, C. H. Bierbaum
- Sub-Committee on Fuel Oil, Raymond H. Danforth
- Sub-Committee on Investigation of the Clinkering of Coal, Lionel S. Marks
- Sub-Committee on Lubrication, Albert Kingsbury
- Sub-Committee on Machine Tools, Leon P. Alford
- Sub-Committee on Safety Valves
- Sub-Committee on Steam Meters, R. J. S. Pigott
- Sub-Committee on Worm Gearing, Fred A. Halsey

Sections, Elliott H. Whitlock
Standard Flanges and Pipe Fittings, Henry G. Stott
Standards for Graphic Presentation, Willard C. Brinton
Student Branches, Frederick R. Hutton
Tellers of Election, Robert H. Kirk
Tolerances in Screw Thread Fits, L. D. Burlingame

SECTIONS COMMITTEES

Chairmen and Secretaries

Atlanta, Earl F. Scott, Park A. Dallis
Birmingham, Roy E. Brakeman, Paul Wright
Boston, A. L. Williston, (Secretary not appointed)
Buffalo, John Younger, (Secretary not appointed)
Chicago, Joseph Harrington, R. M. Thayer
Cincinnati, F. A. Geier, John T. Faig
Detroit (not appointed)
Los Angeles, W. A. E. Noble, Ford W. Harris
Milwaukee, Edward Hutchens, F. H. Dorner
Minnesota, J. V. Martenis, D. M. Forfar
New Haven, H. B. Sargent, E. H. Lockwood
New Orleans, W. B. Gregory, H. L. Hutson
New York, H. R. Cobleigh, A. D. Blake
Philadelphia, Emmet B. Carter, Wm. R. Jones
St. Louis, H. R. Setz, L. A. Day
San Francisco, Frederick W. Gay, C. F. Braun
Worcester, Paul B. Morgan, Edgar H. Reed

[1] A complete list of the officers and committees of the Society will be found in the Year Book for 1916, and in the July, 1916, issue of The Journal.

SOCIETY AFFAIRS

A Record of the Current Activities of the Society, its Members, Council, Committees, Sections and Student Branches; and an Account of Professional Affairs of Interest to the Membership

AS matters of moment in the affairs of the Society required immediate consideration and action, a special meeting of the Council was called for July 27. The following members responded: D. S. Jacobus, *President*, J. Sellers Bancroft, John H. Barr, R. M. Dixon, *Chairman Finance Committee*, A. M. Greene, Jr., James Hartness, C. T. Main, Spencer Miller, H. de B. Parsons, James E. Sague, John A. Stevens, E. H. Whitlock, Wm. H. Wiley, *Treasurer*, and Calvin W. Rice, *Secretary*. By invitation, Charles Whiting Baker, representative of the Society on the Joint Conference Committee of the National Engineering Societies, and Herman Aaron, Esq., general counsel of the Society, were also present.

The important transaction of the meeting, and one of paramount interest to the whole engineering profession, was the unanimous adoption of resolutions receiving the American Society of Civil Engineers into the United Engineering Society, to become one of the Founder Societies in joint ownership, occupancy and administration of the Engineering Societies Building. These resolutions follow:

"WHEREAS, A resolution was heretofore passed by the trustees of United Engineering Society on June 24th, 1915, inviting the American Society of Civil Engineers to consider entering the United Engineering Society as an additional Founder Society, and proceedings were had thereupon as are more particularly set forth in the resolution passed by the Board of Directors of the American Society of Civil Engineers on the twenty-third day of June, 1916, which said resolution is as follows, to wit:

> "WHEREAS, The following resolution was passed by the Trustees of United Engineering Society on June 24th, 1915, to wit:
>
> 'RESOLVED, That out of its desire to welcome the American Society of Civil Engineers into the fraternity of the Founder Societies and with a sense of the increased dignity and usefulness to the engineering profession which this adherence to the American Society of Civil Engineers would contribute, the United Engineering Society hereby desires to express the sentiment in favor of coalition which has been growing, and to invite the American Society of Civil Engineers to consider entering the United Engineering Society as an additional Founder Society; and the President is authorized to appoint a Committee to confer with any corresponding Committee of the American Society of Civil Engineers in the formation of a tentative plan which if this invitation is accepted can be referred on the part of the United Engineering Society to the governing bodies of the Founder Societies for their action.'

and

> "WHEREAS, Such resolution has been approved by the governing bodies of the American Institute of Mining Engineers, The American Society of Mechanical Engineers and the American Institute of Electrical Engineers, and was likewise considered and approved by the Board of Direction of this Society, and
>
> "WHEREAS, Conferences have been held between a Committee representing the United Engineering Society, and a Committee representing this Society, and offers have been made in letters dated July 6th, 1915, August 23rd, 1915, and October 28th, 1915, by the Committee of the United Engineering Society, to the Committee representing this Society, and
>
> "WHEREAS, By special ballot, canvassed June 15th, 1916, 2500 of the Corporate Members of this Society voted in favor of the acceptance of the invitation of the United Engineering Society, and only 390 Corporate Members voted against such acceptance, and
>
> "WHEREAS, On that ballot the sentiment of a majority of those voting on each of the plans submitted was expressed in favor of the plan which provides for the addition of three stories to the present building of the United Engineering Society, and against the plan which does not provide for such additional stories, be it
>
> "RESOLVED, That this Board, acting in behalf of the American Society of Civil Engineers, accepts the invitation of the United Engineering Society made, in behalf of the American Institute of Mining Engineers, The American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, to become one of the Founder Societies, in accordance with the terms and conditions contained in the before mentioned letter, dated July 6th, 1915, as modified by the before mentioned letter, dated August 23rd, 1915, which provide for the construction of three additional stories to the present building of the United Engineering Society, at an estimated cost of $225,000. It is understood, in accordance with the terms of said letters, that the cost to this Society in any event is not to exceed $250,000.
>
> "RESOLVED, That Clemens Herschel, Charles Warren Hunt, and J. V. Davies, be and are hereby authorized for, and in behalf of, this Society, to execute any agreements or other instruments that may be appropriate for carrying into effect, in accordance with the above, the plan whereby this Society shall enter the United Engineering Society as an additional Founder Society, this Society assuming therein an obligation to defray the expenses of such building operations, at a cost not to exceed $250,000."

"NOW BE IT RESOLVED, That the said last mentioned resolution and the plans set forth therein be, and the same are hereby approved, and that D. S. Jacobus and Calvin W. Rice be and they hereby are authorized for and in behalf of this Society to execute any agreements or other instruments that may be appropriate for carrying into effect the aforementioned plan and to cause the corporate seal of this Society to be affixed to any such agreement or instrument."

Actions by the Executive Committee, as recorded in the minutes of the meeting of July 7, 1916, of that committee, were confirmed.

E. G. Spilsbury, John R. Freeman or H. G. Stott, the Society's representatives on the Board of Trustees of the United Engineering Society, were appointed attorneys and proxies of the Society to attend a meeting of the Founder Societies of

the United Engineering Society to vote for the Society upon an increase in the number of trustees of the United Engineering Society from nine to twelve.

Interpretations of the Boiler Code Committee, Nos. 67 to 80 inclusive, and Nos. 49, 61, 67, 69, 74, and 81 to 88 inclusive, were approved with certain corrections and ordered issued. The corrected interpretations are published elsewhere in this number of The Journal under the title Work of the Boiler Code Committee.

J. Sellers Bancroft was appointed a member of the Committee on the Metric System.

Sections in Detroit and in New Orleans were authorized and the following Committee appointed in the latter place: W. B. Gregory, *Chairman;* H. L. Hutson, *Secretary and Treasurer;* R. T. Burwell, E. W. Kerr, and H. F. Rugan.

James E. Sague, Vice-President of the Society, was appointed to represent the President at a meeting of the Board of Trustees of the United Engineering Society to perfect the preliminary arrangements for the reception of the American Society of Civil Engineers into the United Engineering Society.

In connection with the preparation of the Budget for the ensuing year, the Council directed that one-half of the initiation fees should be included in the income and one-half set aside in the reserve fund; that for the up-keep of the Society's furniture and fixtures, a depreciation, repair and renewal fund should be established, and that 15 per cent of the present inventory value should be annually appropriated to this fund, and that mileage for attendance at Council meetings be at the rate of 7 cents per mile, one way.

Matters referred by a previous Council to the Joint Conference Committee of the National Engineering Societies, viz, the subjects of Ethics and of Joint Administration of Sections were referred back by the Conference Committee with the recommendation that the existing committees on these subjects in the several Societies should be brought together in a joint conference, and the Council requested the President to take the initiative to arrange such joint meetings.

The action of the Joint Conference Committee with relation to recommending to the attention of the President of the United States the desirability of legislation relating to the development of water power was approved. Here follows the resolution:

"The Joint Conference Committee of National Engineering Societies believes that the development of the country's undeveloped water power will increase national prosperity; that private enterprise should be encouraged and stimulated to expedite such development; that unnecessary legal burdens should be removed and existing doubts as to the safety of investment eliminated. It commends to the support of engineers all efforts made to secure the fullest publicity as to the underlying facts regarding this subject."

A note regarding water power legislation now pending before Congress appears elsewhere in the Society Affairs Section of this issue of The Journal.

The Council invited the House Committee, under the general direction of the Committee on Meetings, to take charge of the President's Reception at the time of the Annual Meeting, and on account of the anticipated large attendance, it was suggested that this reception be held on the Fifth Floor of the Engineering Societies Building, where better accommodations are available.

The report of the Tellers of Election of Dr. Ambrose Swasey for Honorary Member was read, together with the letter of acknowledgment from Dr. Swasey. This letter appears at the bottom of this page.

A letter was read from Frank J. Sprague, Chairman of the Memorial Committee of The American Institute of Consulting Engineers, asking this Society to join in the erection of a memorial tablet to Alfred Noble, past-officer of this Society. This communication was referred to the Trustees of the United Engineering Society, as a Committee of Trustees has already under consideration a comprehensive scheme for tablets, etc., for the Engineering Societies Building.

A communication with respect to the standardization of machine tools, which had been solicited by the Secretary, was received from L. P. Alford. The Secretary was requested to confer with the Chairman of the Research Committee, and ascertain if the work of standardization had better be undertaken in connection with the work of the Research Committee, or independently.

A request was made to the counsel of the Society, Herman Aaron, Esq., for an opinion as to the part the Society may consistently take in the Minnesota Joint Engineering Board, the proposal for which was noted in the August issue of The Journal.

The Finance Committee reported the condition of the Society up to and including July 31, of which report the following is a resumé:

Book accounts charged this date	$137,486.32
Estimated income for the year	149,570
Expenses incurred to date	124,003.11
Budget appropriation	139,975

The Certificates of Indebtedness having been entirely paid, the total indebtedness of the Society of all kinds is solely the current expenses of the past month, amounting to $14,515.84

against which the Society has in cash and other quick assets $85,798.33

which does not include the trust funds of the Society, all of which are invested.

CALVIN W. RICE, *Secretary.*

LETTER FROM DR. SWASEY

The following letter was received from Dr. Swasey, expressing his appreciation of the action of the Society in electing him an honorary member:

CLEVELAND, OHIO,
July 11, 1916.

PROF. D. S. JACOBUS, PRESIDENT,
The American Society of Mechanical Engineers,
New York.

Dear Professor Jacobus:

I am pleased to receive your favor of the 5th advising me of the action of the Council in electing me an honorary member of the Society. This is a great honor, and I appreciate it more than I have words to express. I regard it one of the gratifying experiences of my life to have been a member of the Society from the time of its organization, but to be placed on the honor roll is indeed a mark of great distinction.

Very truly yours,

(Signed) AMBROSE SWASEY.

INDUSTRIAL PREPAREDNESS

THE returns from the vast industrial inventory made by the Committee on Industrial Preparedness of the U. S. Naval Consulting Board mark a new and vital relation between the business men of America and the Federal Government. The information gathered is the fruit of the work of the army of 30,000 American engineers, members of the national engineering societies, who formed the field force of the Committee organized to find out for the Government the available industrial resources of the nation.

The five months' campaign of the Committee on Industrial Preparedness of the U. S. Naval Consulting Board to obtain an inventory of the country's manufacturing and producing resources for national defense purposes has been remarkable.

In this article are given several interesting examples of replies received from concerns suggesting novel methods of adjusting industries to the needs of conflict.

The committee's plans for educating American manufacturers in time of peace in the requirements of the army and navy in war are provided for in proposed legislation, and excerpts from the same are here given.

The campaign of the committee, with the aid of a volunteer unpaid organization of the members of the national engineering societies, has introduced a new era of the engineer in the preservation of national governments.

The manufacturers of the nation, recognizing the highly qualified and non-partisan personnel of this movement, which has the support of the President, the military heads and the Chamber of Commerce of the United States, have with few exceptions responded with patriotism and interest in this movement for a thoroughgoing industrial preparedness. They were called upon to give comprehensive information on the adaptability of their factories, mills and mines to federal uses from the hour of military mobilization, the data to be held in the strictest confidence for the sole scrutiny and benefit of the war and navy departments of the United States. The business men have met the Committee on Industrial Preparedness and the engineers at least half way in this effort to establish a backbone for the national defense.

Chairman Coffin, Mem.Am.Soc.M.E., calls attention to the reports of State Directors to the effect that all elements of business life in their respective regions unite on the wisdom and practicability of the committee's plans for establishing annual educational orders in small quantities for the manufacture of munitions of war. The idea is to teach American manufacturers now producing, say, farm machinery, how to turn out some one war commodity best suited to their output, and this in time of peace.

NOVEL WAYS OF ADAPTING MANUFACTORIES

The response to the State Director's request to concerns for information for the industrial census has shown a desire to support the work of the committee, and a summary of the letters received discloses in a most interesting and graphic way how the industries of the country could adjust themselves to the needs of conflict.

A large capacity sash-chain maker believed he could with little difficulty produce cartridge clips for rifles and machine guns, and a manufacturer of threshing machinery was sure he could make 600 six-in. shells per day.

A maker of underwear declared he could turn out bandages and other knit goods for the army and navy and Red Cross services, a button maker thought his machines could be used for small munitions work, and a company manufacturing drugs stated that it could turn a considerable portion of its product into an adjunct for making cordite for shells.

One well-known foundry said it was well equipped to turn out tools and machinery for small arms and ammunition, a maker of belting even suggested that he could produce webbing with which to fasten equipment on soldiers, and a famous producer of condensed milk thought he could be of use to his government in time of war.

On the theory that an army is as good as the feet of its men, boot and shoe makers were queried, and showed interest, even enthusiasm, and a smart clothier of the metropolis saw no reason why he, too, could not help Uncle Sam with equipment at the proper time.

A leading Buffalo manufacturer wrote: "We look upon it as a patriotic duty to fill out the blank forwarded to us;" the president of a great railroad wrote at length analyzing the situation in a most sympathetic way, and a maker of pocket knives volunteered to produce various lines of munition supplies.

Several optical makers have pointed out where they could be of practical aid to armies in the field, and a crushed stone company saw where it could play a large part in maintaining good roads against the wear and tear of modern military transportation. An extensive tailoring concern emphasized that the production of uniforms should be standardized, one of the world's leading makers of printing presses placed himself wholly at the command of the state board, and perhaps the greatest municipal transportation system in the United States appointed its chief engineer to serve the committee's purpose.

The head of a great woolen mill wrote: "The constructive policy of the committee is surely the only means by which true preparedness can be arrived at," the leading American manufacturer of farm materials promptly offered to find out what military utilization could be made of its plants in a day of need, and a maker of chocolates, which are so important to modern armies on the march, had very definite views.

A linotype company stated that it has a large quantity of lathes, drills, milling machinery and other tools adapted for the production of shells, fuses, accurate machine tools and small metal parts of any kind requiring extreme precision.

The president of one of the world's chief railroad systems gladly offered his company's shops for the inspection of the state board, an up-state concern now making starting and lighting apparatus for automobiles was quite sure it could furnish small arms, and an elevator company is devoting earnest study as to how it could help the government with its mechanical equipment.

A prominent maker of drop forgings wrote that he would waste no time finding out how his plants could be utilized for

the military forces, and finally, a fountain pen manufacturer gladly offered to analyze his mechanical equipment, and when necessary to adapt it to the benefit of the Government of the United States.

COMPULSORY PREPAREDNESS PROBABLE

The committee's carefully worked out plans to teach American manufacturers now, in time of peace, how, through annual educational orders, to turn out war munitions and all other military and naval supplies when needed, have now been incorporated into legislation which has been passed by both Houses and is, at the time of going to press, awaiting signature by the President.

This legislation is embodied in H. R. 12766, Army Reorganization Bill, and H. R. 16460, Army Appropriation bill. In the former, legal provision is made for the preparation or acquisition by the Government of special aids and appliances for the manufacture of munitions in time of war. In the latter, a Council of National Defense, for the coördination of industries and resources for the national security and welfare, is established.

Extracts from the provisions of these measures follow:

The President, in time of war or when war is imminent, is empowered through the head of any department of the Government, in addition to the present authorized methods of purchase or procurement, to place an order with any individual, firm, association, company, corporation, or organized manufacturing industry for such product or material as may be required, and which is of the nature and kind usually procured or capable of being produced by such individual, firm, company, association, corporation, or organized manufacturing industry.

Compliance with all such orders for products or material shall be obligatory on any individual, firm, association, company, corporation, or organized manufacturing industry or the responsible head or heads thereof, and shall take precedence over all other orders and contracts theretofore placed with such individual, firm, company, association, corporation, or organized manufacturing industry; and any individual, firm, association, company, corporation, or organized manufacturing industry or the responsible head or heads thereof owning or operating any plant equipped for the manufacture of arms or ammunition, or parts of ammunition, or any necessary supplies or equipment for the Army, and any individual, firm, association, company, corporation, or organized manufacturing industry or the responsible head or heads thereof owning or operating any manufacturing plant, which, in the opinion of the Secretary of War shall be capable of being readily transformed into a plant for the manufacture of arms or ammunition, or parts thereof, or other necessary supplies or equipment, who shall refuse to give to the United States such preference in the matter of the execution of orders, or who shall refuse to manufacture the kind, quantity, or quality of arms or ammunition, or the parts thereof, or any necessary supplies or equipment, as ordered by the Secretary of War, or who shall refuse to furnish such arms, ammunitions, or parts of ammunition, or other supplies or equipment, at a reasonable price as determined by the Secretary of War, then, and in either such case, the President, through the head of any department of the Government, in addition to the present authorized methods of purchase or procurement herein provided for, is hereby authorized to take immediate possession of any such plant or plants, and, through the Ordnance Department of the United States Army, to manufacture therein in time of war, or when war shall be imminent, such product or material as may be required; and any individual, firm, company, association, or corporation, or organized manufacturing industry, or the responsible head or heads thereof, failing to comply with the provisions of this section shall be deemed guilty of a felony, and upon conviction shall be punished by imprisonment for not more than three years and by a fine not exceeding $50,000.

* * * * * * *

The Secretary of War shall also make, or cause to be made, a complete list of all privately owned plants in the United States equipped to manufacture arms or ammunition, or the component parts thereof. He shall obtain full and complete information regarding the kind of arms or ammunition, or the component parts thereof, manufactured or that can be manufactured by each such plant, the equipment in each plant, and the maximum capacity thereof. He shall also prepare, or cause to be prepared, a list of privately owned manufacturing plants in the United States capable of being readily transformed into ammunition factories, where the capacity of the plant is sufficient to warrant transforming such plant or plants into ammunition factories in time of war or when war shall be imminent; and as to all such plants the Secretary of War shall obtain full and complete information as to the equipment of each such plant, and he shall prepare comprehensive plans for transforming each such plant into an ammunition factory, or a factory in which to manufacture such parts of ammunition as in the opinion of the Secretary of War such plant is best adapted. (H. R. 12766, SEC. 120.)

* * * * * * *

That the Secretary of War be, and he is hereby, authorized to prepare or cause to be prepared, to purchase or otherwise procure, such gauges, dies, jigs, tools, fixtures, and other special aids and appliances, including specifications and detailed drawings, as may be necessary for the immediate manufacture, by the Government and by private manufacturers, of arms, ammunition, and special equipment necessary to arm and equip the land forces likely to be required by the United States in time of war: PROVIDED, That in the expenditure of any sums appropriated to carry out the purposes of this section the existing laws prescribing competition in the procurement of supplies by purchase shall not goverrn, whenever in the opinion of the Secretary of War such action will be for the best interest of the public service. (H.R. 12766, SEC. 123.)

H. R. 16460 adopts the committee's measure for an industrial reserve, so that in time of war the skilled mechanic shall be kept at home on the job, where his services are most needed to feed the firing line. Extracts from this measure are:

That a council of National Defense is hereby established, for the coördination of industries and resources for the national security and welfare, to consist of the Secretary of War, the Secretary of the Navy, the Secretary of the Interior, the Secretary of Agriculture, the Secretary of Commerce, and the Secretary of Labor.

That the Council of National Defense shall nominate to the President, and the President shall appoint, an advisory commission, consisting of not more than seven persons, each of whom shall have special knowledge of some industry, public utility, or the development of some natural resource, or be otherwise specially qualified, in the opinion of the council, for the performance of the duties hereinafter provided.

* * * * * * *

That it shall be the duty of the Council of National Defense to supervise and direct investigations and make recommendations to the President and the heads of executive departments as to the location of railroads with reference to the frontier of the United States so as to render possible expeditious concentration of troops and supplies to points of defense; the coördination of military, industrial, and commercial purposes in the location of extensive highways and branch lines of railroads; the utilization of waterways; the mobilization of military and naval resources for defense; the increase of domestic production of articles and materials essential to the support of armies and of the people during the interruption of foreign commerce; the development of seagoing transportation; data as to amounts, location, method and means of production, and availability of military supplies; the giving of information to producers and manufacturers as to the class of supplies needed by the military and other services of the Government, the re-

quirements relating thereto, and the creation of relations which will render possible in time of need the immediate concentration and utilization of the resources of the Nation.

That the Council of National Defense shall adopt rules and regulations for the conduct of its work, which rules and regulations shall be subject to the approval of the President and shall provide for the work of the advisory commission to the end that the special knowledge of such commission may be developed by suitable investigation, research, and inquiry, and made available in conference and report for the use of the council; and the council may organize subordinate bodies for its assistance in special investigations, either by the employment of experts or by the creation of committees of specially qualified persons to serve without compensation, but to direct the investigations of experts so employed.

That the sum of $200,000, or so much thereof as may be necessary, is hereby appropriated, out of any money in the Treasury not otherwise appropriated, to be immediately available for experimental work and investigations undertaken by the council, by the advisory commission, or subordinate bodies, for the employment of a director, expert, and clerical expenses and supplies, and for the necessary expenses of members of the advisory commission or subordinate bodies going to and attending meetings of the commission or subordinate bodies.

* * * * * * *

That $250,000 * * * may be used to procure gauges, dies, jigs, tools, fixtures, and other special aids and appliances, including specifications and detailed drawings necessary for the manufacture by the Government and by private manufacturers of ammunition necessary for the use of the land forces of the United States in time of war, and in the purchase of lots of ammunition to complete the object of this proviso the existing laws prescribing competition in the procurement of supplies by purchase shall not govern in orders not to exceed $50,000 in any one case.

That $200,000 * * * may be used to procure gauges, dies, jigs, tools, fixtures, and other special aids and appliances, including specifications and detailed drawings, necessary for the manufacture by private manufacturers, of arms necessary to arm the land forces likely to be required by the United States in time of war, and in the purchase of lots of arms to complete the object of this proviso the existing laws prescribing competition in the procurement of supplies by purchase shall not govern in orders not to exceed $50,000 in any one case. (H. R. 16460.)

In the article Tribute to Dr. E. D. Leavitt on page 653 of the August issue of The Journal, the personnel of the committee on resolutions was incorrectly given. The committee consisted of F. W. Dean, *chairman*, J. S. Coon and A. M. Mattice.

In the death of Sir William Ramsay, science loses one of its most resourceful experimenters, as well as a most daring prognosticator. His fame as a discoverer dates back to 1894, when, with Lord Rayleigh, he demonstrated that atmospheric air contains the previously unknown gaseous element *argon*. He later separated three new gaseous elements, which he named *neon*, *krypton*, and *zenon*, as well as *helium*.

At a recent meeting of the Texas Cotton Seed Crushers' Association the following resolution was adopted:

WHEREAS, The American Society of Mechanical Engineers having prepared a satisfactory code for the standardization of boiler construction to promote the safety of human life and economy in operation, it is hereby

RESOLVED, That the Texas Cotton Seed Crushers' Association, in convention assembled, approves the said boiler code and recommends its adoption by the State of Texas.

The States of Ohio, Pennsylvania and California have accepted the A. S. M. E. Boiler Code unconditionally and have embodied it as a whole in their statutes. In Wisconsin and Indiana, the Code is acceptable as an alternative to the existing requirements.

ROLL OF HONOR

THE Society is desirous of publishing lists of all members enlisted or contemplating enlistment in the National Guard, the Regular Army, the Navy, or in any other capacity in the services of the country. Every member who is, or who knows of any other member who is engaged in the service of the country is requested to notify the Secretary.

The first Roll of Honor was published in the August issue of The Journal. The second, comprising further names received to date, appears below.

HILL, FRANCIS L., Company H, First Virginia Regiment of Volunteers, Brownsville, Texas

NEWCOMB, ROBERT S., Captain, Coast Artillery Corps, New York National Guard. Assigned to 33rd Co., 8th C. D. C.

DAVIS, JAMES H., Second Lieutenant, Coast Artillery Corps, New York National Guard. Assigned to 33rd Co., 8th C. D. C.

WHITTED, THOMAS B., Colonel and Chief of Engineers, North Carolina National Guard

PELLY, JOHN F., Battery A, First Field Artillery, Pennsylvania National Guard

TILLSON, BENJAMIN F., Aide, Naval Consulting Board, Sussex Co., N. J.

ELSEY, H. M., Private, Company L, Fifth Infantry, California National Guard

OHMER, JOHN F., JR., First Lieutenant and Battalion Adjutant, Third Ohio Infantry

MELLEN, WILLIAM H., Machinist's Mate, Second Class, Civilian Cruise

KRAUS, SIDNEY M., Lieutenant (J. G.), U. S. N.

CHURCH, ELIHU CUNNINGHAM, Seventh Infantry, New York

WHITLEY, FREDERIC N., Major, First Battalion, New York Engineers

TUTTLE, W. B., Second Lieutenant, Training Camp Regiment, Fort Sam Houston, Texas

TOLTZ, MAX, Major, Engineering Corps, Minnesota National Guard

ENGINEER SECTION OF OFFICERS' RESERVE CORPS

Since the announcement in the August issue of The Journal of the provision made in the Army Reorganization Bill, awaiting the President's signature, for an Engineer Section of the Officers' Reserve Corps, preliminary steps have been taken by the War Department towards the formation of this corps. By direction of the Chief of Engineers, Lieut. Col. E. Eveleth Winslow, of the Army Engineer Corps, sent a letter on August 8 to all the district engineer officers of the army throughout the country. This letter sets forth the plan for the formation of this corps as follows:

"The importance of engineers in time of war is now universally recognized, and during the past few months steps have been taken to arouse the interest of the engineering profession in the national defense. Congress has now provided a means by which the civil engineers can more than fully prepare themselves for that highest duty of citizens—the defense of our country. An engineer section of officers and enlisted reserve corps has been authorized, and in the opinion of the Chief of Engineers there is for the officers of the Corps of Engineers no more important duty than their active assistance in making a success of the new corps. All the engineers in the country should be informed of the existence of this new corps, and those possessing the necessary qualifications should be enrolled as its members. A close coöperation between our engineer officers and the civilian engineers is therefore necessary, and fortunately the first steps in such coöperation have been already taken by the action of some of the most important of the engineering societies in indorsing the campaign for preparedness and in urging upon Congress the passage of the Officers' Reserve Corps law.

"The following instructions explain how it is intended to organize the engineer section of this corps:

"Each district engineer officer will be a member of a local board, so that the entire area of the country will be covered. The other members of the board will be one medical officer or medical reserve officer (who will be ordered to duty with the board by the department commander on request of the Chief of Engineers), and one officer of the Engineer Officers' Reserve Corps. If practicable it is desired that the Engineer Reserve officer be a member of the branch of the engineering profession to which the candidates belong, i. e., civil, mechanical, electrical, mining, and railway engineering professions. This will require having five separate boards when the number of applicants justifies it.

"When a sufficient number of applications have been received from any district, an examining board will be appointed for that district. Until such reserve officers have been commissioned and thus become available to act on the local boards, the latter will consist of two members only, i. e., the district engineer officer and the medical member."

Regarding the selection of the boards Lieut. Col. Winslow wrote:

"In appointing the boards, the senior officer of the Corps of Engineers on each board will be designated the President thereof; his office will be the office of record, although the junior member must nominally, at least, act as recorder.

"After each board has been appointed, it will endeavor to enlist the interest of each engineer in its territory in the Reserve Corps and will give all necessary information and render all possible assistance to persons desiring to join. The various engineering societies and the prominent technical newspapers and journals will be requested by this office to lay before their members and readers the importance of joining the corps. An order prescribing the regulations for the enlisted Reserve Corps is now in course of preparation.

"An Executive Committee will be formed to pass finally upon all applications for membership to the Reserve Corps of Engineers, and to recommend the grades in which successful applicants shall be commissioned and enlisted. This Executive Committee will be composed of the heads of divisions in the office of the Chief of Engineers; one member of the American Society of Civil Engineers, one member of The American Society of Mechanical Engineers, one member of the American Institute of Electrical Engineers, one member of the American Institute of Mining Engineers, one member of the American Society of Consulting Engineers, one railway operating official.

"After a sufficient number of officers and non-commissioned officers have been appointed, companies and battalions will be organized, officers and non-commissioned officers assigned thereto, and the other enlisted personnel thereof obtained. This will be made the subject of a later letter of instructions."

The principal requirements of the regulations that apply to the Engineer Officers' Reserve Corps are published in General Order No. 32, War Department, July 28, 1916, a copy of which will be furnished by the Chief of Engineers, U. S. Army, Washington, D. C., to any member of the Society on request. The Chief of Engineers will also furnish a form letter of application for commission in the corps.

All members of the Society are able to meet the professional requirements for a commission in this corps. For instance, a candidate for First and Second Lieutenant must be an engineer in the active practice of his profession,—members in the Junior and higher grades meet this requirement; a candidate for Captain must have been in the active practice of his profession for at least eight years and have had responsible charge of work as principal or assistant for two years,—members in the Associate-Member and higher grades meet this requirement; a candidate for Major must have been in the active practice of his profession for at least fifteen years, must have had responsible charge of work for five years and must be qualified to design as well as direct engineering work,—full members of five years standing meet this requirement.

A. A. STEVENSON PRESIDENT OF A. S. T. M.

Archibald Alston Stevenson, Mem.Am.Soc.M.E., vice-president of the Standard Steel Works Company, Philadelphia, was elected president of the American Society for Testing Materials at its recent meeting at Atlantic City. Mr. Stephenson was born in Allegheny City, Pa., in 1862. After being graduated from the high school at Rock Island, Ill., in 1878, he served for one year as rodman on a government survey, and then studied for two years at the University of Illinois. He spent four and one-half years in the service of the Southwark Foundry and Machine Company, Philadelphia, the last year as chief draftsman, and then entered the employment of the Cambria Iron Company, where for two and one-half years he divided his time between the chief engineer's office and the forge and axle plant. In 1888 he became engineer of the Standard Steel Works Company, and five years later superintendent; in 1908 he was elected vice-president of the company.

Mr. Stevenson was vice-president of the Association of American Steel Manufacturers from 1908 to 1911, and president from 1911 to 1914. He is a member of the American Institute of Mining Engineers, the International Association for Testing Materials, and the Engineers' Club of Philadelphia. He was elected to membership in the Society in 1888.

WATER POWER LEGISLATION

Both branches of Congress have passed bills for the granting of permits for power dams and plants in navigable streams. The Senate bill proposes that the Secretary of War shall have authority to grant power permits, under uniform and general terms, conditions and regulations prescribed in the measure. The House bill provides terms and conditions under which dams may be built, to be administered and enforced by the Secretary of War, with the condition that before any plans shall be approved or agreements entered into for the construction of such dams, Congress shall in each case pass a special enabling act granting its consent to the location and construction.

There are several differences of policy in the Senate and House bills on which a conference committee of the Senate and House is endeavoring to reach an agreement, so that a general dam bill can be approved by both houses and become law before the end of the present session of Congress. Some of these differences hinge on the wording of particular sections or clauses; other differences have to do with the question of Government charges and restrictions upon the business of grantees.

The Senate bill requires the grantee to construct any locks and other aids to navigation which may be required by the Secretary of War at the time the dam is built and to operate such locks, etc., without expense to the Government. The House bill requires that the grantee shall construct such locks as the Secretary of War or Congress may at any time deem to be necessary.

Both bills require the grantee to pay a charge for whatever increased water power may be created by improvements constructed by the Government for storage of headwaters of streams, and both bills provide that the grantee shall maintain lights, signals, fishways, etc., and shall pay a tax or rental for use of surplus waters where a power plant is built at a Government dam. In addition to these charges the House bill gives the Secretary of War authority to require the grantee to

pay a tax on the grant itself, the amount of which is left to the discretion of the Secretary and which may be readjusted by him at the end of twenty years and of each ten years thereafter.

Both bills provide that water-power grants shall be irrevocable for fifty years, except for cause, and that at any time after the expiration of fifty years the Government may take over the property, or authorize a new grantee to do so, at a valuation to be mutually agreed upon or fixed by the courts, with no allowance for any rights granted by the Government. The Senate bill, however, proposes that after fifty years the original grantee shall continue in possession, under the original terms and conditions, until the Government decides to take over the property or has a chance to make a better bargain with a new grantee. The House bill terminates the grant absolutely at the end of fifty years and provides that the Secretary of War then make a new grant upon such terms and conditions as existing laws may then require, or may do nothing.

The Joint Conference Committee of the National Engineering Societies wrote to the President of the United States urging that legislation be enacted at this session of Congress.

AMERICAN INDUSTRIAL COMMISSION TO FRANCE

There has just sailed from this country an Industrial Commission to France, which is to make a technical investigation of conditions there, leading to an interchange of ideas to determine by what reciprocal action the United States and France may best develop the resources of the two countries.

The undertaking of this Commission is based upon cordial proposals from the Government of the French Republic,—proposals which came entirely unsolicited and which were the outcome of a recent visit to this country by French commissioners for the purpose of studying conditions here.

The Commission is in charge of the American Manufacturers' Export Association, under whose authority an official report of its work will be issued in due course. Extraordinary and unprecedented facilities have been granted by the French Government to aid the Commission, affording every assurance of a successful outcome.

The investigation will cover all the industries of the United States concerned in French trade, under the following classifications: Prime movers; heavy machinery; machine tools, wire, transmission and textile machinery; milling machinery; electrical apparatus; transportation; importers; synthetic production of chemicals; bankers; factory architects, engineers and contractors.

The Commissioners are men of broad experience in their respective lines—men of national reputation whose coöperation imparts dignity and standing to the enterprise and guarantees a result both conclusive and effective.

Below is a partial list of the personnel of the Commission:

WILLIAM WALLACE NICHOLS, *Chairman*, Assistant Chairman Allis-Chalmers Manufacturing Co., Inc., 50 Church St., New York City.

E. V. DOUGLASS, *General Secretary*, Secretary American Manufacturers Export Association, 160 Broadway, New York City

J. G. BUTLER, Jr., Director Commercial National Bank, Youngstown, Ohio; Vice-President Brier Hill Steel Company.

SAMUEL W. FAIRCHILD, Vice-President Fairchild Bros. & Foster, 76 Laight St., New York City

A. B. FARQUHAR, President, A. B. Farquhar Co., Ltd., York, Pa.

GEO. BURDETT FORD, Member of Geo. B. Post & Sons, 101 Park Ave., New York City.

NOBLE FOSTER HOGGSON, President Hoggson Bros., Inc. (Contractors), 485 Fifth Ave., New York City.

F. J. LEMAISTRE, B.S., M.E., Consultant, E. I. du Pont de Nemours & Co., Wilmington, Del.

JOHN R. MACARTHUR, MacArthur Bros., 120 Broadway, New York City.

DR. C. O. MAILLOUX, Consulting Engineer, 20 Nassau St., New York City.

CURT G. PFEIFFER (Specially recommended by Mr. Maurice Damour), Vice-President Geo. Borgfeldt & Co., 16th St. & Irving Place, New York City.

E. E. RUSSELL, J. I Case Threshing Machine Co., Racine, Wis.

JAMES E. SAGUE, Vice-President Am.Soc.M.E., Former Vice-President American Locomotive Co., New York, and Public Service Commissioner; Address: Poughkeepsie, N. Y.

AMBROSE SWASEY, Hon. Mem.Am.Soc.M.E., President Warner & Swasey Co., Cleveland, Ohio.

E. A. WARREN, Vice-President Universal Winding Co., 95 South St., Boston, Mass.

ARIZONA MEETING OF A. I. M. E.

The American Institute of Mining Engineers will hold a meeting in Arizona from September 18 to 25, 1916. A special train will be provided to convey members and their guests from New York City and other points to Arizona for this meeting. The meeting will include a special train tour of the Arizona mining districts, technical sessions being held at several centers *en route*. Among the side trips is included an automobile ride over the Apache Trail and a visit to the Grand Canyon of the Colorado.

A cordial invitation to attend the meeting has been extended by the Institute to all the members of our Society, and the Secretary of the A.I.M.E., Mr. Bradley Stoughton, 29 West 39th Street, New York, will be glad to send a little booklet giving full information regarding the meeting and tour to any member of the Society interested.

A. I. E. E. PACIFIC COAST CONVENTION

The Pacific-Coast Convention of the American Institute of Electrical Engineers will be held in Seattle, Wash., September 5 to 9, 1916. At the technical sessions the following papers will be presented:

A Distributing System for Domestic Power Service from Commercial and Engineering Standpoints
Some Features of Domestic Electric Cooking and Heating
Temperature Rise of Insulated Lead Cables
Inductive Interference as a Practical Problem
Testing for Defective Insulators on High-Tension Transmission Lines
The High-Voltage Potentiometer
An Artificial Transmission Line with Adjustable Line Constants
Characteristics of Admittance Type of Wave-Form Standard
Insulator Failures Under Transient Voltages.

In addition to the technical sessions numerous entertainment features have been arranged. The program for the day sessions on the 7th will be supplied by the Northwest Electric Light and Power Association. At the evening session of that day a lecture on The Illumination of the Panama-Pacific Exposition will be delivered by W. D'A. Ryan.

Further information regarding this meeting may be obtained from the Secretary of the A.I.E.E., Mr. F. L. Hutchinson, 29 West 39th Street, New York City.

APPLICATIONS FOR MEMBERSHIP

TO BE VOTED ON AFTER OCTOBER 10, 1916.

MEMBERS are requested to scrutinize with care the following list of candidates who have filed applications for membership in the Society. These are subdivided according to the grades for which their ages qualify them and not with regard to professional qualifications, i.e., the ages of those under the first heading place them under either Member, Associate or Associate-Member, those in the next class under Associate-Member or Junior, and those in the third under Junior grade only. Applications for change of grading are also posted.

The Membership Committee, and in turn the Council, urge the members to assume their share of the responsibility of receiving these candidates into membership by advising the Secretary promptly of any one whose eligibility for membership is in any way questioned. All correspondence in regard to such matters is strictly confidential, and is solely for the good of the Society, which it is the duty of every Member to promote. Unless objection is made to any of the candidates posted, by October 10, 1916, and providing satisfactory replies have been received from the required number of references, these candidates will be balloted upon by the Council. Those elected to membership will be notified by the Secretary about November 15, 1916.

NEW APPLICATIONS

FOR CONSIDERATION AS MEMBER, ASSOCIATE OR ASSOCIATE MEMBER

ALPERN, MAXWELL,
American Engineering Co., Philadelphia, Pa.

ALMY, THOMAS R., JR., Plant Engineer,
Falulah Paper Co., Fitchburg, Mass.

ASHMEAD, CHARLES B., District Manager,
The Richardson-Phenix Co., Pittsburgh, Pa.

AYER, WILLIAM T., Superintendent,
McKinnan-Terry Drill Co., Dover, N. J.

BALDWIN, RAYMOND S., Buffalo Works Manager,
J. H. Williams & Co., Buffalo, N. Y.

BALZARI, ROBERT A., Engineer,
Westinghouse Electric & Mfg. Co., San Francisco, Cal.

BARNES, EUGENE L., District Manager,
American District Steam Co., Seattle, Wash.

BATES, HARRY H., Vice-President,
Joliet Oil Tractor Co., Joliet, Ill.

BEEBE, HERBERT A., Chief Draftsman,
Fitchburg Machine Works, Automatic Dept., Fitchburg, Mass.

BIDWELL, PAUL W.,
B. F. Perkins & Son, Inc., Holyoke, Mass.

BRANDT, CARL A. W., Mechanical Engineer,
Locomotive Superheater Co., New York

BROWN, HOLCOMBE J., Operating Manager,
Keystone Plaster Co., Chester, Pa.

BROWNE, THOMAS A., Employment Manager,
Ashcroft Mfg. Co., Bridgeport, Conn.

BRYANT, PERCY J., Heating and Ventilating Engineer,
U. S. Military Academy, West Point, N. Y.

BUERSTATTE, FRED W., Associate Professor,
Washington State College, Pullman, Wash.

BUGGE, SVEN B., Engineer,
Wausau Sulphate Fibre Co., Mosinee, Wis.

CALDWELL, CHARLES A., Consulting Engineer, Macon, Ga.

CARTER, ROBERT A., JR., Assistant Engineer of Manufacture,
Consolidated Gas Co. of N. Y., New York

CARTER, WILLIAM D., Designing Engineer, San Jose, Cal.

CONVERY, JOHN J., Consulting Engineer, New York

COOPER, ARTHUR, Chief Draftsman,
Manila Railroad Co., Manila, P. I.

COPONY, ALFRED, Master Car Builder,
Grand Trunk Rwy., Western Lines, Chicago, Ill.

COX, JOHN W., Chief Engineer,
Erie Malleable Iron Co., Erie, Pa.

CURTIS, ALLEN, Manager of Manufacturing,
International Paper Co., New York

DALLY, CHARLES A., Manager Reserve Natural Gas Co. of La.,

DAY, WILLIAM A., General Sales Manager,
The Frost Manufacturing Co., Chicago, Ill.

DENNIS, FREDERICK L.,
U. S. Local Inspector of Boilers, New Haven, Conn.

DETTE, ARTHUR E. L., Chief Engineer,
Alan Wood Iron & Steel Co., Conshohocken, Pa.

DIXON, J. ALFRED, Vice-President,
Safety Car Heating & Lighting Co., New York

DORSEY, WALTER A., Mechanical Engineer,
The Bonney Floyd Co., Columbus, Ohio
Shreveport, La.

DU BOSE, GEORGE P., Superintendent,
Holt Manufacturing Co., Stockton, Cal.

DUNLEVY, D. W., General Superintendent,
Colonial Steel Co., Pittsburgh, Pa.

DURAM, ARTHUR E., President and Chief Engineer,
The New York Steam Co., New York

ELA, EVERETT W., Research Engineer,
Waltham Watch Co., Waltham, Mass.

ENGEL, GODFREY, JR., Engineer in charge of Sugar Dept.,
Gerdes & Co., New York

ENTWISLE, EDWARD F., Mechanical Engineer,
Bethlehem Steel Co., Steelton, Pa.

FELGAR, JAMES H., Dean, College of Engineering,
University of Oklahoma, Norman, Okla.

FIELD, HENRY P., Assistant Mechanical Engineer,
American Car & Fdy. Co., Berwick, Pa.

FINCH, GEORGE L., Engineering Superintendent,
Hood Rubber Co., E. Watertown, Mass.

FREEMAN, HERBERT A., Chief Draftsman,
Crocker Wheeler Co., Ampere, N. J.

FREEMAN JULIAN B., Chief Engineer,
Webster Engineering Co., Chicago, Ill.

FOSDICK, WILLIAM P.,
With Walter G. Franz, Consulting Engineer, Cincinnati, Ohio

GALLAHER, CHARLES W., 1st Lieutenant,
Iowa Engineers, Brownsville, Tex.

GILLHAM, CHARLES A., Vice-President, Executive,
The New York Steam Co., New York

GODA, PETER H., Motive Power Inspector,
Penn. Lines, Fort Wayne, Ind.

GREENE, EDWARD A., Captain U. S. Marine Corps, Washington, D. C.

HADLEY, FREDERICK V., Chief Engineer,
American Incandescent Heat Co., Inc., Boston, Mass.

HAGENAH, RUDOLPH E., Chief Engineer of Plants,
New York Steam Co., New York

HANSON, EDWARD S., Editor,
The Cement Era, Chicago, Ill.

HAWKINS, PAUL D., Engineer,
Framingham Machine Works, Framingham, Mass.

HEULINGS, SAMUEL M.,
With Sheffield Farms-Slawson Decker Co., New York

HEWITT, CARL T., Engineer
Remington Arms Union Metallic Cartridge Co., Bridgeport, Conn.

HICKOK, WILLIAM O., 4TH, Goshen, N. Y.

HILL, ANTHONY S.,
With American Saw Mill Machinery Co., Hackettstown, N. J.

HULL, BURTON E., Department Engineer,
The Texas Co., Houston, Tex.

JACKMAN, CHESTER C.,
With Massachusetts Saw Works, Springfield, Mass.

JASCHKA, JOHN H.,
With The National Malleable Castings Co. of Cleveland,
San Francisco, Cal.

JANN, VICTOR,
General Electric Co., Cincinnati, Ohio

JERNEE, HOWARD B., Engineer,
E. I. du Pont de Nemours & Co., Barksdale, Wis.

JOHNSTON, A. LANGSTAFF, JR., Consulting Engineer,
Southern Associate of Moses, Pope & Messer, Cons. Engrs.,
Richmond, Va.

JOLINE, EMMET A., Factory Superintendent,
S. S. White Dental Mfg. Co., Prince Bay, N. Y.

JUDY, WILBUR H., Engineering Inspector,
City of San Diego, Cal.

KLAUDER, LOUIS T., Assistant Engineer, Mechanical Construction,
Philadelphia Rapid Transit Co., Philadelphia, Pa.

KNOWLTON, EDGAR, Electrical Engineer,
General Electric Co., Schenectady, N. Y.

KOTZ, EMIL F., Mechanical Engineer, Syracuse, N. Y.

KRISHNAIYENGAR, HALSUR, Supervisor of Sloyd,
West Circle, Mysore, India.

LAY, ROBERT P., Superintendent of Inspection,
Curtiss Aeroplane & Motor Corp., Buffalo, N. Y.

LEATHERS, HARRY H.,
With Schumaker-Santry Co., Boston, Mass.

LEHR, CHARLES E., Chief Engineer of Construction,
Bethlehem Steel Co., South Bethlehem, Pa.

LONGLEY, FRANCIS B., Inspector,
Associated Pipe Line Co., San Francisco, Cal.

LOWMAN, ROY L., Ordnance Engineer,
Bethlehem Steel Co., Bethlehem, Pa.

McINTYRE, MELVIL B., Secretary,
Steel Fabricating Co., Chicago Heights, Ill.

MACKAY, ALFRED, Chief Engineer,
John Lang Paper Co., Philadelphia, Pa.

MAIER, FRED, Proprietor,
Mechanical Pattern Works, Los Angeles, Cal.

MAYO, EDMUND C., General Manager,
Worcester Pressed Steel Co., Worcester, Mass.

MESERVE, FRANK A., Superintendent of Construction Dept.,
Ashcroft Mfg. Co., Bridgeport, Conn.

MOSSMAN, ROY L., Chief Engineer,
Municipal Water & Power Plant, Humboldt, Tenn.

MOTTINGER, BYRON T., Electrical Engineer,
Fort Dodge, Des Moines & So. R. R., Boone, Ia.

MUNRO, ROBERT E., Chief Inspector,
Hartford Steam Boiler Inspection and Insurance Co.,
Baltimore, Md.

NEIDIG, W. N., Mechanical Engineer,
Fred T. Ley & Co., Inc., Springfield, Mass.

NELSON, MARCUS C., Manager,
R. B. Phillips Manufacturing Co., Worcester, Mass.

NEWMAN, CHARLES H., Designer,
209 Broadway, New York

NOBLE, A. C., Master Mechanic,
Empire Steel & Iron Co., Mt. Hope Div., Wharton, N. J.

OAK, JAMES H., General Foreman, Production Dept.,
New England Westinghouse Co., Springfield, Mass.

OBERLIN, EDGAR G., Lieutenant U. S. Navy, Engineer,
Republique d'Haiti, c/o Department of State, Washington, D. C.

PARKS, EDWARD F., Chief Engineer,
Universal Winding Co., Providence, R. I.

PEARSON, SAMUEL, President and Chief Engineer,
C. I. C. Engine Mfg. Co., Portland, Ore.

POGUE, GEORGE,
With Fulton Iron Works, St. Louis, Mo.

PRATT, HAROLD H., Assistant Consulting Engineer,
Phelps, Dodge & Co., Inc., Douglas, Ariz.

PRINCE, DUFFIELD, Engineering Department,
N. Y. C. & H. R. R. Co., New York

RATHJENS, GEORGE W., Vice-President,
Twin City Brick Co., St. Paul, Minn.

REICHARD, GEORGE A.,
With Worthington Pump & Machinery Corp., Los Angeles, Cal.

RICKETSON, WILLIAM E., Mechanical Engineer,
C., C., C. & St. L. Rwy. Co., Beech Grove, Ind.

ROBERTS, J. EDWARDS, Secretary,
L. L. Harr Corporation, New York, N. Y.

ROBERTS, JNO. D.,
With Pere Marquette R. R., Detroit, Mich.

ROUTH, G. H., Chief Operating Engineer, Niagara Falls Mill,
International Paper Co., Niagara Falls, N. Y.

SCHRANZ, FREDERICK G., Manager Hydraulic Department,
Southwark Foundry & Machine Co., Philadelphia, Pa.

SEABURY, GEORGE E., Engineer,
Edison Electric Illuminating Co., Boston, Mass.

SETTI, SRIRAM V., Superintendent,
Government Mechanical Engineering School,
Bangalore, Mysore State, India

SHAW, BENJAMIN C., Master Mechanic,
Warren Cotton Mills, West Warren, Mass.

SLATER, WILLIAM A., Superintendent,
Fort Worth Refinery of Gulf Refining Co., Fort Worth, Tex.

SMITH, PRESTON M.,
With Allied Machinery Co. of America, New York

SOLOMON, GABRIEL R., Consulting Engineer,
Solomon-Norcross, Altoona, Pa.

STEVENS, RAY P., President,
Mahoning & Shenango Railway & Light Co., Youngstown, Ohio.

STOELTZING, HARRY E., Assistant Superintendent of Power,
Brooklyn Rapid Transit System, Brooklyn, N. Y.

STUART, THOMAS E., Power Station Supt.,
Omaha Electric Light & Power Co., Omaha, Neb.

SWIFT, HENRY, Chief Draftsman, Munitions Dept.,
American Steam Gauge & Valve Mfg. Co., Boston, Mass.

THAYER, ABBOT A., Secretary,
Oakley Machine Tool Co., Cincinnati, Ohio

TOWNSEND, GEORGE R., Secretary,
East Jersey Pipe Corporation, Paterson, N. J.

VAN DER HOEVEN, CONSTANT, Manager New York Office,
Lindeteves & Stokvis, at Amsterdam, Holland, New York

WADDELL, TARVER W., Southern Manager,
Pawling & Harnischfeger Co., Milwaukee, Wis.

WARD, HARRY A.,
With Sterling Blower Co., Hartford, Conn.

WATEROUS, CHARLES A., Assistant General Manager,
Waterous Engine Works Co., Ltd., Brantford, Ont., Canada.

WATT, JAMES, Mechanical Engineer,
Krehbiel Co., Chicago, Ill.

WELLS, CLEMENT, Vice-President of Sarco Co., Inc., New York

WESTWATER, ANDREW, Marine Engine Draftsman,
Moore & Scott Iron Works, Oakland, Cal.

WHITE, HAROLD C., Factory Manager,
The Holt Manufacturing Co., Stockton, Cal.

WHITESIDE, SAMUEL P., Mechanical Engineer,
Davison Chemical Co., Curtis Bay, Md.

WILDER, FRANK E., Consulting Engineer,
Southworth Machine Co., Portland, M

WILLIAMS, JARVIS, JR., Manager Commercial Div.,
U. M. C. Works, Remington Arms U. M. C. Co., Bridgeport, Conn.

WONFOR, WILLIAM H., Specialist in Technical Advertising,
Dayton, Ohio.

WOODCOCK, JOHN W., Head of Engineering, Drafting and Estimating Departments,
Crane Co., Bridgeport, Conn.

WOODWORTH, CARL B., General Foreman Locomotive Department,
Mt. Clare Shops, B. & O. R. R., Baltimore, Md.

WOOTTON, HARRY C., Asst. General Inspector,
Hopkins & Allen Arms Co., Norwich, Conn.

WORK, DAVID W., Draftsman,
Braden Copper Co., Rancagua, Chile

WRIGHT, ARTHUR C., Superintendent and Consulting Engineer,
East Springfield Plant, New England Westinghouse Co.,
E. Springfield, Mass.

WYANT, ROBERT E., Superintendent,
New Haven Gas Light Co., New Haven, Conn.

FOR CONSIDERATION AS ASSOCIATE-MEMBER OR JUNIOR

ARDILLA, RICARDO, Special,
N. Y. Central Railroad Shops, Depew, N. Y.

ABBEY, FRANK H., Boston Manager,
Gifford-Wood Co., Boston, Mass.

BANGS, GEORGE H., Assistant Superintendent Machine Department,
H. B. Smith Co., South Side Works, Westfield, Mass.

BARCLAY, WILLIAM, Chief Engineer,
R. & J. Dick, Ltd., Passaic, N. J.

BARNUM, EDWARDS W., Efficiency Engineer,
Winchester Repeating Arms Co., New Haven, Conn.

BEEHLER, WEYMAN P., Senior Engineer Officer,
U. S. S. Columbia, c/Navy Department, Washington, D. C.

BEEKLEY, WALDRON C., Manager Heater Dept.,
Whitlock Coil Pipe Co., Hartford, Conn.

BORNHORST, AUGUST H., Marine Engine Draftsman,
Navy Yard, Puget Sound, Bremerton, Wash.

BRANDEL, S. W., Factory Manager,
U. S. Ball Bearing Mfg. Co., Chicago, Ill.

BROOKS, ALFRED A., Assistant Engineer,
Turbine Research Department, General Electric Co., Lynn, Mass.

BROWN, WENDELL S., Engineer,
with F. P. Sheldon & Son, Providence, R. I.

BUCHANAN, MOSES R., General Manager,
Silver City Power Co., Silver City, N. Mex.

BUCKLEY, AMBROSE T., Electrician,
Department of Public Charities, Sea View Hospital, City of N. Y.

CHAMPNEY, RALPH P., Chief Engineer,
Constr. Department, The Graton & Knight Mfg. Co.,
Worcester, Mass.

COWELL, FRANKLIN W.,
With The Great Western Sugar Co., Denver, Colo.

CREDO, JULIUS,
With Louisville Drying Machinery Co., Louisville, Ky.

CULLEN, JAMES W.,
With Cambria, Midvale and Worth Bros. Steel Companies,
Pittsburgh, Pa.

CUMMINGS, LAWRENCE T., Member of Staff.
Miller Franklin & Co., Efficiency Engineers, New York
DEVINE, CHARLES P., Vice-President,
J. P. Devine Co., Buffalo, N. Y.
DODGE, JAMES S., Secretary and General Manager,
Sulpho-Chemical Sprinkler Corporation, New York
DUSENBERY, HENRY,
With Thos. P. Ford Co., Inc., New York
DYER, HORACE T., Lieutenant U. S. N.,
Chief Engineer, U. S. S. Montana, New York
EVANS, DAVID F., Assistant to Mechanical Superintendent,
Hopewell Works, City Point, Va.
FINK, JOHN B.,
With Cosden Oil & Gas Co., Shamrock, Okla.
FITZPATRICK, CLARENCE J., Chief Engineer,
Cleveland Worm & Gear Co., Cleveland, Ohio
HAWLEY, KENT A., Assistant Engineer,
Gibbs & Hill, Pennsylvania Station, New York
GUNKEL, FREDERICK H., JR., Member of Plant Engineers' Force,
American Telephone & Telegraph Co., New York
HEWLETT, VAN WYCK, JR., Draftsman,
J. Edward Ogden Co., Woodmere, L. I., N. Y.
HOOKER, OLIVER W., Draftsman,
Birmingham Iron Foundry, Derby, Conn.
HORTON, RALPH, Chief Engineer,
Sheffield Farms-Slawson Decker Co., New York
HUGHES, WALTER J.,
With Larimer-Hughes Co., Los Angeles, Cal.
KERR, CHARLES P.,
With The Goodyear Tyre & Rubber Co., Sydney, Australia
LEE, CLIFFORD, Mechanical Engineer,
India Rubber Co., New Brunswick, N. J.
LEWIS, J. CLIFFORD, Industrial and Mechanical Engineer,
Indianapolis, Ind.
LOVELY, JOHN E., Mechanical Engineer,
F. R. Patch Manufacturing Co., Rutland, Vt.
LUETSCHER, OLIVER P., Chief Engineer,
Ill. Zinc Co., Peru, Ill.
LUNDGREN, SVEN E., Chief Engineer Stoker Section,
Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa.
LYNDE, CHARLES C., Engineering Editor,
The National Iron & Steel Publishing Co., Pittsburgh, Pa.
MARTIN, CLIFFORD A., Chief Draftsman,
J. H. Williams & Co., Brooklyn, N. Y.
MELONEY, CHARLES W., Assistant Engineer,
Henry I. Lea, Cons. Engr., Chicago, Ill.
MENGES, HARRY P., Superintendent No. 12 Mill,
Jones & Laughlin Steel Co., Pittsburgh, Pa.
MURPHY, WALTER B., Superintendent, Frankford Plant, Chemical Dept., The Barrett Co., Philadelphia, Pa.
NORRMAN, AXEL E., Designing Engineer,
Moulton Engineering Corp., Portland, Me.
POLGLAZE, RICHARD A., Superintendent Water Dept.,
City of Gadsden, Ala.
RAYMOND, HAROLD E., Consulting Engineer,
New Orleans, La.
REILLY, CHARLES J., Assistant to Superintendent,
The Sandusky Cement Co., Bay Ridge, Ohio
SCHIKENDANZ, LOUIS H., Assistant in Mechanical Department,
Cleveland Cliffs Iron Co., Ishpeming, Mich.
SERMULIN, FRED E., Resident Engineer,
Alpha Portland Cement Co., Manheim, W. Va.
SHAW, MAX M.,
With Eston Dodson & Co., Inc., Bethlehem, Pa.
SOSSONG, RAYMOND A., Operating Manager,
Searchlight Co., Chicago, Ill.
SPECK, WILLIAM C., General Inspector,
The Buckeye Steel Castings Co., Columbus, Ohio
SPIEGELHALTER, CHARLES, Designer,
The Pusey & Jones Co., Wilmington, Del.
STEPHENS, FRED S., Superintendent Engineering,
Chulas Tea Co., Ltd., Matelli, P. O. India
TOWNSEND, ARTHUR J., Chief Engineer,
Berger Mfg. Co., Canton, Ohio
VUILLEUMIER, ALBERT, Designing Engineer,
New Departure Mfg. Co., Bristol, Conn.
VICKERS, CHAUNCY H., Efficiency Draftsman,
American La France Fire Engine Co., Inc., Elmira, N. Y.
WEILER, RUDOLPH B., Mechanical Engineer,
The Sharples Separator Co., West Chester, Pa.
WETJEN, HENRY W.,
With Alberger Pump & Condenser Co., New York
WICHUM, VICTOR,
With C. J. Tagliabue Mfg. Co., Brooklyn, N. Y.
WILHELM, CAPTAIN WALTER M., Vice-President,
Eddystone Ammuniton Corp., Eddystone, Pa.
WUESTNER, CLARENCE J., Mechanical Draftsman,
E. I. du Pont de Nemours & Co., City Point, Va.
YOUNG, JOHN H., District Lubrication Engineer,
The Texas Co., Youngstown, Ohio

FOR CONSIDERATION AS JUNIOR

BAKER, IRVING C.,
With American Blower Co., Detroit, Mich.
BALLANTINE, JOHN H., Assistant Superintendent,
Neptune Meter Co., Long Island City, N. Y.
BARR, JAMES A., Draftsman,
Pittsburgh Valve, Foundry & Construction Co., Pittsburgh, Pa.
BAYLIS, ROGER V., Engineering Dept.,
Neptune Meter Co., Long Island City, N. Y.
BLIXT, GUSTAF F., JR., Designer,
J. Edward Ogden Co., New York
BOYLE, WALTER W., Assistant to Superintendent,
Central Power Plant, Estate Henry W. Oliver, Pittsburgh, Pa.
BYRON, LEROY T.,
With Westinghouse, Church, Kerr & Co., New York
CATHER, WILLIAM A.,
With Worthington Pump & Mchy. Co., Harrison, N. J.
COHEN, EDGAR F.,
With Centrifugal Pump Dept., Worthington Pump & Machinery Corp., Harrison, N. J.
CRONAN, CLIFFORD B.,
With Remington Arms Co., Bridgeport, Conn.
DAHLSTRAND, JOSEF Y., Chief Engineer,
Kerr Turbine Co., Wellsville, N. Y.
DE YOUNG, HERMAN,
With Hopkins & Allen Arms Co., Norwich, Conn.
DREYER, ELMER J.,
With Illinois Steel Co. South Chicago, Ill.
DUVIC, FRANK R., Inspector,
U. S. Engineer Office, New Orleans, La.
EDDY, CARLTON W., Dorchester, Mass.
EDWARDS, GILBERT M., Draftsman,
Terry Steam Turbine Co., Hartford, Conn.
EICHENBERG, MARK A., Maintenance Dept.,
Bosch Magneto Co., Plainfield, N. J.
ELBELT, WILLIAM H.,
With Chino Copper Co., Hurley, N. Y.
FLANNAGAN, ERIC G., Engineer,
The W. Virginia Pulp & Paper Co., Covington, Va.
GEOTZENBERGER, RALPH L., Engineer, Power and Mining Dept.,
General Electric Co., Schenectady, N. Y.
GLOVER, JOHN S., Office of Inspector Eng. Material, U. S. N.,
General Electric Co., Schenectady, N. Y.
GOEDKOOP, WALTER C.,
With The New York Steam Co., New York
GREEN, LLOYD F.,
With Bethlehem Steel Co., Bethlehem, Pa.
GROSNER, GERALD D., Mechanical Engineer,
Sharpless Specialty Co., West Chester, Pa.
HOLMGREN, FREDERICK W., Mechanical Engineer, New York
HOYT, ALBERT J.,
With American Steel & Wire Co., Trenton, N. J.
HUBBARD, GEORGE M. C., Graduate Student, Higganum, Conn.
HUMMEL, FERDINAND G.,
With Babcock & Wilcox Co., Bayonne, N. J.
INMAN, CHESTER M.,
With Pratt & Inman, Worcester, Mass.
JACKSON, WILLIAM G.,
With Spaulding & Jennings Works, Crucible Steel Co., of America, Jersey City, N. J.
JACOBS, ADOLPH, Mechanical Draftsman,
United Printing Mch. Co., Boston, Mass.
JOHNSON, JOHN B., Inspector Aeroplanes,
U. S. Government, S.S.L., Washington, D. C.
JUDE, HENRY,
With Manning, Maxwell & Moore, Inc., New York
KEENAN, GEORGE M., Engineer, Service Dept.,
Washington E. & M. Co., Chicago, Ill.
KEET, CLARENCE T., Engineer,
With Schutte & Koerting Co., Philadelphia, Pa.
KENDALL, EDGAR H., Assistant Engineer,
Standard Steel Works Co., Burnham, Pa.
KEOGH, JERE K., Erecting Engineer,
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
KOUWENHOVEN, FRANK W., Brooklyn, N. Y.
KRAUT, HANS B.,
Joseph T. Ryerson & Sons, Chicago, Ill.
LANNING, JOHN G.,
With The Ashcroft Mfg. Co., Bridgeport, Conn.
MARSHALL, KENNETH I., Mechanical Engineer,
The Western Precipitation Co., Los Angeles, Cal.

MERRIAM, CARROLL F., Instructor,
Worcester Polytechnic Institute, Worcester, Mass.
MERRIAM, I. B., JR., President,
Chattanooga Boiler & Tank Co., Chattanooga, Tenn.
MERSHON, JOHN W., Mechanical Engineer,
Remington Arms & Ammunition Co., Bridgeport, Conn.
MULLER, RAYMOND W., Asst. Maintenance Engr.,
Bosch Magneto Co., Plainfield, N. J.
NEWCOMB, BENJAMIN R., Patent Attorney,
Washington, D. C.
NICE, EVERETT W., Mechanical Engineer,
Western Electric Co., Inc., Chicago, Ill.
NOYES, JONATHAN A.,
With Sullivan Machinery Co., Chicago, Ill.
NORDHEIMER, ALBERT,
With New York Central Railroad, West Albany, N. Y.
O'BRIEN, THOMAS C.,
With De La Vergne Machine Co., New York
OVERMIRE, WILFRED J., Assistant Fuel Inspector,
C. C. C. & St. L. Ry., Indianapolis, Ind.
PEASE, MAXFIELD,
With The Stanley Works, New Britain, Conn.
PETER, ALBERT G., Efficiency Engineer,
Chain Belt Co., Milwaukee, Wis.
PICCARD, JULES E., Student Graduate,
Polytechnic Institute, Brooklyn, N. Y.
PURDY, ASA R., Engineer,
With Martin & De Remer, Consulting Engineers, New York
RAYMOND, THOMAS E., Engineer,
Metz Motor Car Co., Waltham, Mass.
RIKER, FREDRICK, Assistant to Superintendent, Dept. of Distribution,
East River Gas Co., Long Island City, N. Y.
ROSEN, CARL G. A., Mechanical Engineer,
Dow Pump & Diesel Engine Co., Alameda, Cal.
RYDER, FREDERICK W., Efficiency Engineer,
Lehigh Valley Coal Co., Wilkes-Barre, Pa.
SAALFRANK, ROYAL B.,
With De Long Hook & Eye Co., Philadelphia, Pa.
SCHULTZ, ARTHUR F., Machine Designer,
Westinghouse Machine Co., E. Pittsburgh, Pa.
SEARLE, DANA A., Draftsman,
Ordnance War Dept., Washington, D. C.
SEMMEL, JOHN W., Assistant Chief Operating Engineer,
New Jersey Zinc Co., Palmerton, Pa.
SMITH, HORACE L., JR., Secretary,
Horace L. Smith & Co., Inc., Petersburg, Pa.
SMITH, WILLIAM H., Draftsman,
Alpha Portland Cement Co., Easton, Pa.
TROOP, EUGENE F., Boiler Superintendent,
E. I. Du Pont de Nemours & Co., Hopewell, Va.
UEHLING EDWARD,
With Pittsburgh Valve & Fittings Co., Barberton, Ohio
VAN KENNEN, HAROLD H., Assistant to Elec. Engr.,
Rochester & Pittsburgh Coal & Iron Co., Punxsutawney, Pa.
WACHTLER, WILLIAM B., Assistant to Engineer of Tests,
Hyatt Roller Bearing Co., Newark, N. J.
WORK, CLAYTON W., Erecting Engineer,
Westinghouse Elec. & Mfg. Co., New York

APPLICATION FOR CHANGE OF GRADING

PROMOTION FROM ASSOCIATE-MEMBER

BRAUN, CARL F., President,
C. F. Braun Co., San Francisco, Cal.

PROMOTION FROM JUNIOR

BALZ, GEORGE A., Vice-President, Manager and Treasurer,
Didier-March Co., Perth Amboy, N. J.
BROWN, RICHARD P., President,
The Brown Instrument Co., Philadelphia, Pa.
BURDSALL, ELLWOOD, Secretary,
Russell-Burdsall-Ward Bolt & Nut Co., Port Chester, N. Y.
BUSHNELL, JAMES E., Engineer,
Robins Conveying Belt Co., New York
CASE, ALBERT H., Mining Engineer,
General Development Co., New York
CASE, MILO M., Consulting Mechanical Engineer, Chicago, Ill.
DEARBORN, WILLIAM L., Resident Engineer,
Barclay, Parsons & Klapp, New York
DISERENS, PAUL, Engineer of Tests, Laidlaw Works,
Worthington Pump & Mchy. Corp., Cincinnati, Ohio
FIELD-FRANK, CROSBY, Chief Engineer,
Standard Aniline Products, Inc., Wappingers Falls, N. Y.
GFRÖRER, ALBERT H., Engineer, Indus. Truck Dept.,
Samuel L. Moore & Sons Corp., Elizabeth, N. J.
HIDER, GEORGE T., Partner,
Bell & Rider, Lake Providence, La.
HILDENBRAND, HARRY, General Superintendent,
Houston Cotton Oil Mill, Houston, Tex.
NORTHRUP, FRANCIS B., Charge of Drawing Room,
The Charles Burroughs Co., Newark, N. J.
PATTERSON, PETER C., Chief Engineer,
National Tube Co., Pittsburgh, Pa.
PULIS, WILLIAM E.,
With H. L. Gantt, Consulting Engineer, as Industrial Engineer,
Newark, N. J.
REINICKER, NORMAN G., Assistant to Chief Engineer of Power Plants,
New York Edison Co., New York
RICHTER, ARTHUR W., Dean of Engineering,
University of Montana, Bozeman, Mont.
SONN, GEORGE P., Engineer,
Bridgeport Brass Co., Bridgeport, Conn.
WILLIAMS, RICHARD G., Special Investigator,
Norton Co., Worcester, Mass.

SUMMARY

New applications	258
Application for change of grading:	
Promotion from Associate-Member	1
Promotion from Junior	19
Total	278

SUMMARY SHOWING AVERAGE AGE AND POSITIONS OF APPLICANTS ON BALLOT CLOSING JUNE 29, 1916

Average age of applicants:	
Members	39
Associates	42
Associate-Members	32
Juniors	23
Chief Engineers and Asst. Ch. Engineers	5
Construction Engineers	5
Consulting Engineers	4
Designers	6
Draftsmen	6
Chief Draftsmen	4
Editors and Associate Editors	2
Estimator (Asst.)	1
Executives: Presidents, Vice-Presidents, Treasurers, Secretaries, and Managers	11
Inventor	1
Instructors	2
Laboratory	2
Mechanical Engineers and Assistant Mechanical Engineers	14
Production Engineers	2
Professor	1
Professor (Associate)	1
Sales Manager	1
Superintendents	5
Superintendents (Assistant)	7
Students	1
Student Apprentice	2
Works Manager (Assistant)	1
Miscellaneous	17

GEOGRAPHICAL LIST

(Applications for promotion from any grade will be indicated by the initials of that grade)

Alabama

Gadsden—Polglaze, R. A.

Arizona

Douglas—Pratt, H. H.

California

Alameda—Rosen, C. G.
Los Angeles—Hughes, W. J.
Maier, F.
Marshall, K. I.
Reichard, G. A.
Oakland—Westwater, A.
San Diego—Judy, W. H.
San Francisco—Balzari, R. A.
Braun, C. F. (A. M.)
Jaschka, J. H.
Longley, F. B.
San Jose—Carter, W. D.
Stockton—DuBose, G. P.
White, H. C.

Canada

Brantford—Waterous, C. A.
Chile—Work, D. W.

Colorado

Denver—Cowell, F. W.

Connecticut

Bridgeport—Browne, T. A.
Cronan, C. B.
Hewitt, C. T.
Lanning, J. G.
Merchon, J. W.
Meserve, F. A.
Sonn, G. P.
Williams, J., Jr.
Woodcock, J. W.
Bristol—Vuilleumier, A.
Derby—Hooker, O. W.
Hartford—Beckley, W. C.
Edwards, G. M.
Ward, H. A.
New Britain—Pease, M.
New Haven—Barnum, E. W.
Dennis, F. L.
Wyant, R. E.
Norwich—DeYoung, H.
Wootton, H. C.

Delaware

Wilmington—Spiegelhalter, C.

District of Columbia

Washington—Beehler, W. P.
Greene, E. A.
Johnson, J. B.
Newcomb, B. R.
Oberlin, E. G.
Searle, D. A.

Georgia

Macon—Caldwell, C. A.

Illinois

Chicago—Brandel, S. W.
Case, M. M. (J.)
Copony, A.
Day, W. A.
Dreyer, E. J.
Freeman, J. B.
Hanson, E. S
Keenan, G. M.
Kraut, Hans B.
McIntyre, M. B.
Meloney, C. W.
Nice, E. W.
Noyes, J. A.
Sossong, R. A.
Watt, J.
Joliet—Bates, H. H.
Peru—Luetscher, O. P.

Indiana

Beech Grove—Ricketson, W. E.
Fort Wayne—Goda, P. H.
Indianapolis—Lewis, J. C.
Overmire, Wilfred J.

Iowa

Boone—Mottinger, B. T.

Louisiana

Lake Providence—Hider, G. T.
New Orleans—Duvic, F. R.
Raymond, H. E.
Shreveport—Dally, C. A.

Kentucky

Louisville—Credo, J.

Maine

Portland—Norrman, A. E.
Wilder, F. E.

Maryland

Baltimore—Munro, R. E.
Woodworth, C. B.
Curtis Bay—Whiteside, S. P.

Massachusetts

Boston—Abbey, F. H.
Hadley, F. V.
Jacobs, A.
Leathers, H. H.
Seabury, G. E.
Swift, H.
Dorchester—Eddy, C. W.
Fitchburg—Almy, T. R., Jr.
Beebe, H. A.
Framingham—Hawkins, P. D.
Holyoke—Bidwell, P. W.
Lynn—Brooks, A. A.
Springfield—Jackman, C. C.
Neidig, W. N.
Oak, J. H.
Wright, A. C.
Waltham—Ela, E. W.
Raymond, T. E.
Watertown—Finch, G. L.
Westfield—Bangs, G. H.
West Warren—Shaw, B. C.
Worcester—Champney, R. P.
Inman, C. M.
Mayo, E. C.
Merriam, C. F.
Nelson, M. C.
Williams, R. G.

Michigan

Detroit—Baker, I. C.
Roberts, J. D.
Ishpeming—Schikendanz, L. H.

Minnesota

St. Paul—Rathjens, G. W.

Missouri

St. Louis—Pogue, G.

Montana

Bozeman—Richter, A. W. (J.)

Nebraska

Omaha—Stuart, T. E.

New Jersey

Ampere—Freeman, H. A.
Bayonne—Hummel, F. G.
Dover—Ayer, W. T.
Elizabeth—Gfrörer, A. H. (J.)
Hackettstown—Hill, A. S.
Harrison—Cather, W. A.
Cohen, E. F.
Jersey City—Jackson, W. G.
Newark—Northrup, Francis B.
Pulis, W. E. (J.)
Wachtler, W. B.
New Brunswick—Lee, C.
Passaic—Barclay, W.
Paterson—Townsend, G. R.
Perth Amboy—Balz, G. A.
Plainfield—Eichenberg, M. A.
Muller, R. W.
Trenton—Hoyt, A. J.
Wharton—Noble, A. C.

New Mexico

Silver City—Buchanan, M. R.

New York

Albany—Nordheimer, A.
Brooklyn—Kouwenhoven, F. W.
Martin, C. A.
Piccard, J. E.
Stoeltzing, H. E.
Wichum, V.
Buffalo—Baldwin, R. S.
Devine, C. P.
Lay, R. P.
Depew—Ardilla, Ricardo
Elmira—Vickers, C. H.
Goshen—Hickok, W. O.
Hurley—Elbelt, W. H.
Long Island City—Ballantine, J. H.
Baylis, R. V.
Riker, F.
New York—Blixt, G. F., Jr.
Brandt, Carl A. W.
Buckley, A. T.
Bushnell, J. E. (J.)
Byron, L. T.
Case, A. H. (J.)
Carter, R. A., Jr.
Convery, J. J.
Cummings, L. T.
Curtis, A.
Dearborn, W. L. (J.)
Dixon, J. A.
Dodge, J. S.
Duram, A. E.
Dusenbery, H.
Dyer, H. T.
Engel, G., Jr.
Gillham, C. A.
Goedkoop, W. C.
Gunkel, F. H., Jr.
Hagenah, R. E.
Hawley, K. A.
Heulings, S. N.
Holmgren, F. W.
Horton, R.
Jude, H.
Newman, C. H.
O'Brien, T. C.
Prince, D.
Purdy, A. R.
Reinicker, M. G. (J.)
Roberts, J. E.
Smith, P. M.
Van der Hoeven, C.
Wells, C.
Wetjen, H. W.
Work, C. W.
Niagara Falls—Routh, G. H.
Port Chester—Burdsall, E. (J.)
Schenectady—Glover, J. S.
Goetzenberger, R. L.
Knowlton, E.
Syracuse—Kotz, Emil F.
Wappingers Falls—Field, Frank C. (J.)
Prince Bay—Joline, E. A.
Wellsville—Dahlstrand, J. Y.
West Point—Bryant, P. J.
Woodmere—Hewlett, V. W., Jr.

Ohio

Barberton—Uehling, E.
Bay Bridge—Reilly, C. J.
Canton—Townsend, A. J.
Cincinnati—Diserens, P. (J.)
Fosdick, W. F.
Jann, V.
Thayer, A. A.
Cleveland—Fitzpatrick, C. J.
Columbus—Dorsey, W. A.
Speck, W. C.
Dayton—Wonfor, W. H.
Youngstown—Stevens, R. P.
Young, J. H., Jr.

Oklahoma

Norman—Felgar, J. H.
Shamrock—Fink, J. B.

Oregon

Portland—Pearson, S.

Pennsylvania

Altoona—Solomon, G. R.
Berwick—Field, H. T.
Bethlehem—Green, L. F.
Lowman, R. L.
Shaw, M. M.
Burham—Kendall, E. H.
Chester—Brown, H. J.
Conshohocken—Dette, A. E. L.
Easton—Smith, W. H.
Eddystone—Wilhelm, W. M.
Erie—Cox, J. W.
Palmerton—Semmel, J. W.
Philadelphia—Alpern, Maxwell
Ashmead, C. B.
Barr, J. A.
Boyle, W. W.
Brown, R. P. (J.)
Keet, C. T.
Klauder, L. T.
Mackay, A.
Menges, H. P.
Murphy, W. B.
Saalfrank, R. B.
Schranz, F. G.
Schultz, A. F.
Pittsburgh—Cullen, J. W.
Dunlevy, D. W.
Lundgren, S. E.
Lynde, C. C.
Patterson, P. C. (J.)
Punxsutawney—Van Kennen, H. H.
Steelton—Entwisle, E. F.
South Bethlehem—Lehr, C. E.
West Chester—Grosner, G. D.
Weller, R. B.
Wilkes-Barre—Ryder, F. W.
Providence—Parks, E. F.

Rhode Island

Providence—Brown, W. S.
Parks, E. F.

Tennessee

Chattanooga—Merriam, I. B., Jr.
Humboldt—Massman, R. L.

Texas

Brownsville—Gallagher, C. W.
Fort Worth—Slater, W. A.
Houston—Hildenbrand, H. (J.)
Hull, B. E.

Vermont

Rutland—Lovely, J. E.

Virginia

City Point—Evans, D. F.
Wuesther, C. J.
Covington—Flannagan, E. G.
Hopewell—Troop, Eugene F.
Petersburgh—Smith, H. L., Jr.
Richmond—Johnston, A. L., Jr.

Washington

Bremerton—Bornhorst, A. H.
Pullman—Buerstatte, F. W.
Seattle—Barnes, E. L.

West Virginia

Manheim—Sermulin, F. E.

Wisconsin

Barksdale—Jernee, H. B.
Milwaukee—Keogh, J. K.
Peter, A. G.
Waddell, T. W.
Mosinee—Bugge, S. B.

Australia

Sydney—Kerr, C. P.

India

Matelli—Stephens, F. S.
Mysore—Krishnaiyengar, H.
Setti, S. V.

Phillippine Islands

Manila—Cooper, A.

PERSONALS

IN these columns are inserted items concerning members of the Society and their professional activities. Members are always interested in the doings of their fellow-members, and the Society welcomes notes from members and concerning members for insertion in this section. All communications of personal notes should be addressed to the Secretary and items should be received by the 18th of the month in order to appear in the succeeding issue of The Journal.

ANNOUNCEMENTS.

HERBERT L. THOMPSON has accepted a position with the A. S. Cameron Steam Pump Works, St. Louis, Mo.

ROBERT B. BROWNLEE has accepted a position with the Reed-Prentice Company of Worcester, Mass.

W. M. ARMSTRONG has resigned his position as vice-president and sales manager of the Corrugated Bar Company, Buffalo, N. Y.

AUSTIN D. KEABLES has accepted the position of mechanical engineer for the Slatersville Finishing Company, Slatersville, R. I.

E. P. HAINES has accepted a position as mechanical engineer with the Curtis and Company Manufacturing Company of St. Louis, Mo.

DAN L. ROYER has been transferred from Milwaukee to the Chicago office of The Ocean Accident and Guarantee Corporation, Ltd.

ROBERT W. HUNT received the honorary degree of Doctor of Engineering at the recent commencement at Rensselaer Polytechnic Institute.

WILLARD C. BRINTON, consulting engineer, specializing on freight terminal and factory location work, recently returned from a business trip to China and Japan.

HARRY L. HORNING of the Waukesha Motor Company, Waukesha, Wis., has been nominated as one of the councillors of the Society of Automobile Engineers. He will serve for two years.

THOMAS H. ALLEN has withdrawn from the Hoshall Machinery Company, Memphis, Tenn., with which firm he was connected as a partner, and is now engaged in consulting engineering practice.

FRED G. LUNDGREN has been transferred from the Terre Haute, Ind., plant of the American Car and Foundry Company to the position of master mechanic at the Milton, Pa., plant of the company.

CHANGES OF POSITION.

ARTHUR L. LEWIS, formerly with L. F. Fales, Walpole, Mass., has accepted the position of superintendent with Sleeper and Hartley, Inc., Worcester, Mass.

P. J. FREEMAN has resigned from the professorship of applied mechanics in Kansas State College to become engineer of tests for the Pittsburgh Testing Laboratory.

L. S. RICHARDSON, consulting engineer with the Morgan Clark System Company, Rochester, N. Y., has become associated with W. S. Barstow and Company, Inc., New York, N. Y.

SAMUEL J. HOEXTER, instructor in mechanical engineering, University of Michigan, has been appointed manager of the Engineers' Society of Pennsylvania, Harrisburg, Pa.

ANTON HANSEN has severed his connection as chief draftsman with the Kelly and Jones Company, Greensburg, Pa., and has become affiliated with the Crane Company, Bridgeport, Conn.

THOMAS F. GITHENS, until recently associated with the American Sugar Refining Company, Brooklyn, N. Y., has become affiliated with the American Synthetic Dyes, Inc., Newark Transfer, N. J.

WALTER N. WALMSLEY, formerly general manager of the Sao Paolo (Brazil) Tramway, Light and Power Company, Ltd., has been appointed general manager of the Alabama Power Company.

JOHN W. MORTON, formerly of the designing department of the McIntosh and Seymour Corporation, Auburn, N. Y., has been appointed chief draftsman of the Baltimore Oil Engine Company, Baltimore, Md.

GEORGE S. WHEATLEY, formerly instructor of mechanical engineering, University of Pennsylvania, has become associated with the Cambria Steel Company, Johnstown, Pa., in the engineering department.

FERDINAND JEHLE has resigned his position as laboratory engineer with The Automobile Club of America, and has accepted the position of service engineer with The Aluminum Castings Company, Cleveland, O.

FREDERICK W. STARR, until recently publicity manager of The Pope Manufacturing Company, Westfield, Mass., has joined the force of the Toledo Scale Company of Toledo, O., with offices in Hartford, Conn.

MELBERT W. TABER, formerly construction engineer with the Packard Motor Car Company, Detroit, Mich., has been made manager of the Detroit office of the Asbestos Protected Metal Company of Pittsburgh, Pa.

FRANK G. BOLLES, formerly manager of *International Trade*, an export journal published in Chicago, has been elected vice-president of the Russian Trade Corporation of America, Maritime Building, New York City.

EDGAR E BURNET has entered the employ of the Western Mines Supply Company, San Francisco, Cal., in the capacity of Manager. He was formerly associated with the Judson Manufacturing Company of the same city.

LEWIS F. MOODY, for eight years a member of the faculty of Rensselaer Polytechnic Institute, has resigned as professor of hydraulic engineering and will act as consulting engineer for the I. P. Morris Company, Philadelphia.

W. F. ROCKWELL has resigned his position as chief industrial engineer of Clinton H. Scovell and Company, to become assistant general manager and works manager of The Torbensen Gear and Axle Company of Cleveland.

HENRY J. HANZLIK has resigned his position as mechanical engineer of the De Laval Steam Turbine Company, Trenton, N. J., and has accepted the position of consulting engineer of the Kerr Turbine Company, Wellsville, N. Y.

W. H. KAVANAUGH, who for 15 years has been a member of the faculty of the College of Engineering at the University of Minnesota, has accepted the professorship of experimental engineering in the Towne Scientific School of the University of Pennsylvania.

Q. R. NOLAN has assumed the duties of resident engineer at the LaGrange, Ga., works of the Hillside Cotton Mills. He was formerly connected with the Park A. Dallis Company, Atlanta, Ga., in the capacity of superintendent of construction in charge of surveys.

ARTHUR W. MACNABB has entered the employ of the National Meter Company, Brooklyn, N. Y., in the capacity of mechanical draftsman. He was formerly affiliated with the engineering department and inspection division of the Fidelity and Casualty Insurance Company, New York.

ALBERT T. KELLER, formerly identified with the Indiana Steel Company, Chicago, Ill., has accepted the position of chief engineer of construction for the Bethlehem Steel Company at Sparrows Point Md., and will have charge of the extensive new work at the Maryland plant.

DOUGLAS B. WRIGHT, formerly connected with the steam and chemical testing department of the Philadelphia Electric Company, Philadelphia, Pa., has accepted the position of test engineer in the steam engineering department of the Worth Brothers Company of Coatesville, Pa.

HENRY ANDERSON, JR., until recently connected with the New York Fire Insurance Exchange, New York, N. Y., as inspector of the automatic sprinkler department, has accepted a position with E. I. du Pont de Nemours and Company, Wilmington, Del., in the capacity of assistant engineer in connection with fire protection work.

GEORGE H. BLAKELEY, structural engineer with the Bethlehem Steel Company, has been made president of the newly organized Bethlehem Steel Bridge Company, which is to carry on the structural business of the Bethlehem Steel Company and the business formerly conducted by the bridge department of the Pennsylvania Steel Company.

JOHN CALDER has been appointed works manager and assistant to vice-president H. H. Pinney of the Bridgeport works of the Remington Arms-Union Metallic Cartridge Company, Inc. Mr. Calder has recently been associated with the banking house of Willett, Sears and Company of Boston, Mass., and has served as an advisory engineer to a number of New England industrial interests.

APPOINTMENTS.

S. E. KEEFE has been appointed New York representative of The Franklin Oil and Gas Company, Bedford, Ohio.

FRANK E. LEAHY has been promoted to the position of steam and hydraulic engineer of the National Tube Company, Pittsburgh, Pa.

A. G. WILLIAMS, assistant master mechanic of the Pennsylvania Lines West, has been appointed assistant engineer of motive power, succeeding L. B. Jones.

E. J. BURDICK, superintendent of power stations for the Detroit (Mich.) United Railways, has been appointed assistant general manager of the corporation.

FRANK E. HOWELLS, superintendent of shops of the Steelton plant of the Bethlehem Steel Company, has been advanced to the position of assistant mechanical engineer of the plant.

E. L. MAYALL has recently been appointed plant engineer of the Holt Manufacturing Company, Stockton, Cal. Mr. Mayall was formerly connected with the company as head of the implement department.

GEORGE F. SWAIN, professor of civil engineering, Harvard University and Massachusetts Institute of Technology, has been chosen as one of three arbitrators of the dispute over the plans for rehabilitating the Galveston causeway, by the interurban railway and the county.

WILLIAM H. BOEHM was appointed vice-president of the Fidelity and Casualty Company, New York City, at a recent meeting of the board of directors of the company. Mr. Boehm still retains the superintendency of the departments of steam boiler and flywheel insurance.

ARTHUR N. TALBOT, professor of municipal and sanitary engineering, University of Illinois, has been chosen as one of three arbitrators of the dispute that has arisen over plans for the rehabilitation of the Galveston causeway, by the three steam railways interested. The degree of Doctor of Engineering was conferred on Professor Talbot in June by the University of Michigan.

NECROLOGY

HARRY A. HAAS

Harry A. Haas was born at Tamaqua, Pa., on March 31, 1887. In June, 1902, he was graduated from the Tamaqua High School following which he became a clerk in his father's general store. In the summer of 1906 he entered Mount Herman School, in Massachusetts, from which he was graduated in August, 1907. He then entered Lehigh University and graduated with first senior mechanical honors in 1911. During the summer of 1909 he was employed as a teacher of science at Mount Herman School and during the summer of 1910, he was employed in the gun shop of the Bethlehem Steel Company. Following his graduation from Lehigh University, he entered the employ of the Winchester Repeating Arms Company which position he held up to the time of his death. He was employed in the capacity of equipment engineer for the cannon, case, annealing, washing and packing shops and for special machinery.

Mr. Haas was a member of Lehigh Alumni Association. He became a member of this Society in 1915. He was drowned in Lake Bantam on July 15, 1916.

AMOS GRANVILLE HOSMER

Amos Granville Hosmer was born in Hubbardston, Mass., on October 2, 1861. He received his early education in the home schools, and at the age of twenty, he learned the machinists' trade at the works of F. Copeland at Sterling, Mass.

He later became connected with the Arnold Print Works in North Adams, Mass., as mechanical engineer where he remained ten years. For the eight years following this, he was at Clinton, Mass., at the Lancaster Mills, also as mechanical engineer. In 1915, he moved to Lowell, Mass., where he held the position of mechanical superintendent for the Merrimack Manufacturing Company.

Mr. Hosmer was a member of several lodges and a member of the Cotton Manufacturers' Association. He became a member of this Society in 1906. Mr. Hosmer died following an operation on July 22, 1916.

JUDSON H. BOUGHTON

Judson H. Boughton was born at Rochester, N. Y., on January 10, 1881. He received his early education at the Fairfield Military Academy and was graduated from Cornell University in June, 1903.

From 1907 to 1915 he was interested in the operation of light, water, gas and street railways in the South and Southwest. During that time he was secretary and treasurer of the National Light Improvement Company, a New Jersey holding company; consulting engineer of the Ft. Worth Light and Power Company of Ft. Worth, Texas; president of the Citizens Railway Company and the Waco Gas Company of Waco, Texas; consulting engineer for the Hot Springs Water Company, the Hot Springs Gas Company, and the Hot Springs Street Railway Company of Hot Springs, Ark.; president of the National Light & Power Company, a New Jersey holding company; president of the Fulton Electric Light and Power Company of Fulton, Ky.; president of the Hickman Light and Water Company of Hickman, Ky.; president of the Prairie County Public Utility Company of Prairieville, Mo.; consulting engineer for the St. Francis Railroad of Mo.; and consulting engineer on various other properties. During the past two or three years, Mr. Boughton has been devoting his time to the boat industry and in this connection he organized and was president of the St. Louis Yacht and Boat Company and the Great Lakes Boat Building Corporation of Milwaukee to which he was giving all of his attention at the time of his death.

Mr. Boughton was a member of the American Institute of Electrical Engineers, the American Street Railway Association, the National Electric Light Association. He was also a member of the Racket Club, and the City Club of St. Louis, the University Club of Milwaukee and the Milwaukee Yacht Club and the Chicago Yacht Club. He became a member of the Society in 1903. He died at Milwaukee, Wis., on July 29, 1916.

CHARLES KIRCHHOFF

Charles Kirchhoff was born at San Francisco, on March 28, 1853. After receiving his education in the schools of this country, he completed his education in Germany where he was graduated from the Royal School of Mines at Clausthal, Saxony, in 1874.

Returning to the United States, he was employed as chemist at the Delaware Lead Refinery in Philadelphia until 1877. In that year, he became assistant editor of the *Metallurgical Review* and the following year he held the same position with the

Iron Age of which he afterward became editor and part owner for more than twenty years. He was also from 1881 until 1884 the assistant editor of the *Mining Journal*. In the latter year he became again associated with the *Iron Age*, this time as associate editor. When he relinquished this position in 1889, it was to become the editor in chief, a position which he held until 1910, when he retired from business. During the time he was in control of this magazine, it became one of the leading engineering publications of the country. During this time, also, he was for many years vice-president and general manager of the David Williams Company, retiring from this connection in 1910.

From 1883 until 1906 Mr. Kirchhoff was a special agent of the United States Geological Survey for the collection of statistics on the production of lead, copper and zinc. He was the author in 1910 of Notes on Some European Iron Districts.

Mr. Kirchhoff was a member of the American Institute of Mining Engineers, of which society he was president from 1898 until 1899. He also was a member of the American Iron and Steel Institute of Great Britain, the Verein Deutscher Eisenhuettenleute, and an honorary member of The Franklin Institute of Philadelphia. He was trustee and treasurer of the United Engineering Society of New York and last year was elected a trustee of the Engineers' Club of New York. He was also a member of the Century Club. He became a member of this Society in 1882. He died at his summer home in Wannamassa, N. J., on July 23, 1916.

EMPLOYMENT BULLETIN

THE Secretary considers it a special obligation and pleasant duty to make the office of the Society the medium for assisting members to secure positions, by putting them in touch with special opportunities for which their training and experience qualify them, and for helping anyone desiring engineering services. The Society acts only as a clearing house in these matters.

POSITIONS AVAILABLE

In forwarding applications, stamps should be enclosed for transmittal to advertisers; applications from non-members should be accompanied by a letter of reference or introduction from a member, such reference letter to be filed by the Society. Copy for notices should be in hand by the 18th of the month.

ENGINEER. Technical graduate preferred. Experienced in design of open feed water heaters, softeners, etc. Good position to right person. Write fully, giving details of experience and references. 102

SALESMAN AND DRAFTSMAN, on elevating and conveying machinery and light structural work. Preference given to men who would develop into salesmen after training in general work of company in order to become thoroughly familiar with product. Salary $1500 to $1700. Apply by letter with object of personal interview. Location New York State. 179

DETAIL DRAFTSMAN, on structural and mechanical work. Salary about $100 to $125. State experience and salary expected. Location Kansas. 231

TECHNICAL GRADUATE, age 30 to 35, with practical experience in manufacture and building of steam and hydraulic machinery. Man preferred with wide shop experience and capable of directing men. Location Ohio. Interview will be arranged only after examination of applicant's statement of qualification, records and compensation expected. 328

DESIGNER, technical graduate experienced in design of small intricate machinery. Location New York. 424

ASSOCIATE PROFESSOR for university in Missouri, to teach elementary and advanced steam machinery, steam turbines and advanced machine design. Salary about $1800. 427

ASSISTANT FOREMAN in sub-department for development of auto-starting batteries. One having storage battery experience preferred. Salary $21. Location New York State. 441

SUPERINTENDENT for machine shop and brass foundry. Liberal salary for A1 man. State qualifications, age and salary. 442

EXPERIENCED OFFICE MAN with executive training, capable of taking control of an entire office staff. Location Canada. 444

ASSISTANT WORKS MANAGER, exceptionally good opportunity. American parentage, technical education, not over 35, machine shop experience. 455

PRODUCTION SUPERINTENDENT. Man of exemplary habits and character; very dependable. Experience in manufacturing nad operation of machine tools, as planers, drills, forging machines, presses, etc. Hours from 7 a.m. to 5:30 p.m. Must be disciplinarian and good mechanic; 150 to 200 men employed. Location Middle West. 460

PRODUCTION MAN, for cartridge factory in Kansas. Salary $5 to $10 per diem. Main problems are discipline for mixed labor, scheduling orders, rate setting, etc. 465

YOUNG ENGINEER who has made specialty of cement plants, with three or four years practical work since graduation. To take charge of cement plant department of concern manufacturing, crushing and handling plants and cement plant parts. Location Kent, England. 467

YOUNG TECHNICAL GRADUATE, two to four years out of college, to train into sales work for New York concern. 469

ROLLING MILL EXPERT, thoroughly experienced. 470

DESIGNER in general line of conveying and materials-handling machinery, with practical knowledge of shop construction work. Position offers good opportunity for advancement. State age, experience, education, salary desired to start. 473

TEACHER for department of mechanical engineering in Southern University. Graduate engineer with machine shop experience. Work in the university will be instructing in machine shop and steam laboratory. Capable man should work to professorship either in mechanical engineering or machine shop practice. Salary $1500. 474

AGENCY desired for high grade Diesel type oil engine in territory surrounding Kansas City. 475

TOOL DESIGNER. Man who can design and make calculations on special tool jigs and fixtures. Preferably man with actual shop experience and technical education. 476

DRAFTSMAN, who has had considerable experience with the design and installation of boilers, stokers, coal bunkers and coal handling machinery. Capable of designing foundations for boilers and supports for concrete overhead coal bunkers. Liberal salary. Location Pittsburgh, Pa. 477

DRAFTSMAN, experienced on small tool, jig and fixture designing; preferably in connection with small arms and ammunition works. Location Canada. 478

SUPERINTENDENT AND CHIEF ENGINEER for Diesel engine central station of 500-h.p. units in Western state. Must be responsible, efficient superintendent and competent workman-like chief with some experience in Diesel engines. 479

CHIEF DRAFTSMAN OR ASSISTANT ENGINEER with following requirements: First, thoroughly familiar with metric system and able to convert to English units, or vice versa. Second, read and understand French language. Third, familiar with standard practice as applied to drafting, shop management and shop production. Fourth, thoroughly familiar with specifications as applied to materials, bills of materials, etc. Fifth, knowledge of tool design and methods used in production of small brass parts. 484

SHOP SUPERINTENDENT for old established foundry and machine works near New York. Investment desired. 482

DRAFTSMAN with valve experience. 485

SUPERINTENDENT with experience in factory manufacturing small brass parts and who thoroughly understands manufacture from design of tools to shipping. Name confidential. Apply by letter. 486

MECHANICAL ENGINEER AND DESIGNER OF HIGH GRADE MACHINERY who can follow latest machine shop foundry and pattern shop practice, be original, investigate present methods from data secured, develop machinery and conveyors, in proper sequence, to handle mechanically all material from raw stock to finished product. Four or five years experience in same line of work. State age, experience, education, nationality, former connections, salary received, references, when available. Confidential. Location Detroit. 492

SHOP ACCOUNTANTS of experience who have made good wanted for Canadian firm. 493

YOUNG ENGINEER, with fair knowledge of drafting and chemistry, to look after testing work in bleachery plant. Location New Jersey. 500

YOUNG TECHNICAL GRADUATE for planning department. Man with one or two years experience will receive preference. Location Massachusetts. 501

TOOL DESIGNER, experienced in jig and fixture work, for well known machine-tool factory in Massachusetts. 502

LIBRARIAN, for Engineering Library of Sibley College, Cornell University. Engineering graduate with ability to translate German fluently. In addition to routine work librarian would be expected to advise and assist students in use of library, abstract articles, make translations and render assistance to the faculty. Considerable portion of time would be available for study and other purposes. Salary for first year $800. Two months vacation during summer and several days during Christmas and Spring recesses. 503

MEN AVAILABLE

Only members of the Society are listed in the published notices in this section. Copy for notices should be in hand by the 18th of the month, and the form of the notice should be such that the initial words indicate the classification. Notices are not repeated in consecutive issues.

MECHANICAL ENGINEER. Eight years experience in design and manufacture of stationary and aeronautical engines, including jig, tool and foundry work. Desires position as engineer-in-charge or superintendent of gas engine shop. I-288.

MECHANICAL ENGINEER. Eight years experience in heat-treating, testing, forging and micro-structure of steel. Desires position where experience may be used either as executive or semi-executive in production or purchasing department. 1-289

BRANCH OFFICE MANAGER. Wide business experience, good negotiator of large or intricate transactions. Now trustee and managing director for large interests and operating several businesses. Desires position demanding general ability of high order. Available January 1, 1917. I-290

DESIGNER. 1897 graduate, age 38. Several years experience in designing Corliss engines, refrigerating machinery, ice plants and refrigerating plants. For past five years chief engineer for leading ice plant builder in middle west. I-291

PRODUCTION ENGINEER. Technical graduate, age 34. Strong disciplinarian and successful handler of men; organizing and executive ability; well versed in efficiency, rate setting, cost accounting and modern shop management. Desires position along lines of foundry, machine shop or sheet metal work. Compensation to be based on results. I-292

ASSISTANT SUPERINTENDENT. 18 years varied experience in interchangeable manufacturing. Now with concern employing 1800. Wishes connection with reliable company where growing opportunity is assured. I-293

MEMBER. Stevens graduate, age 37, married. Eleven years practical experience in U. S. and abroad in general power station design, engineering and construction. Also five years experience in engineering, administrative and sales department of manufacturing corporations. Desires connection with manufacturing company, with eventual investment of some capital. Knows German and French. At present employed. I-294

CHIEF DRAFTSMAN or ASSISTANT MECHANICAL ENGINEER or INSTRUCTOR IN ENGINEERING BRANCHES. Graduate. Experienced designer of machinery, structural iron and small automatic machines. I-295.

REPRESENTATIVE. Mechanical engineer, with extensive shop and office experience. Desires to become associated with, or represent in New York City, large industrial interests engaged in domestic and foreign trade. I-296

DESIGNER. Experienced on locomotives, gasoline motors, special machinery and tools; practical machinist; technical education; good personality; working knowledge of Spanish and German. Seeks opportunity to work into export sales. Salary moderate. Associate-Member, 32. I-297

SALES ENGINEER, SALES MANAGER or DISTRICT MANAGER. Age 35, graduate mechanical engineer. Ten years experience with constantly increasing sales; power plant equipment and power transmission lines. Salary or commission. At present employed, but ready to make change for position offering good prospects. I-298.

MECHANICAL ENGINEER OF COAL MINES. Ten years experience in design, installation and operation of mechanical equipment of coal mines. Specialist in boiler plant operation and as combustion engineer for coal sales department. I-299

MECHANICAL and MINING ENGINEER, speaking several languages and with wide experience in management of manufacturing and selling engineering specialties, such as time fuses, military rolling sticks, gold placer machines, structural steel, foundry works, water and gas meters, aluminum die-castings and automobiles, now employed in such a capacity, wishes a similar position. Would also entertain representation of manufacturing concern in Europe. Previously represented American concerns abroad as technical and commercial director for engineering specialties and ammunition. Best references furnished. Salary to start $6000 in America; $6000 plus expenses abroad. I-300

MANAGER, SUPERINTENDENT or SALES ENGINEER. M.E. (Lehigh University). Several years experience in management of mechanical and purchasing departments of railroad, coal mining, and industrial corporations; extensive experience as sales engineer in railroad equipment, organizer and executive. Qualified to fill position of manager of industrial plant or coal mining company, or superintendent of motive power of railroad. Can successfully represent manufacturers of machinery, power plant equipment, iron and steel. I-301

ENGINEER or MANAGER'S ASSISTANT. Junior member, graduate M.E., varied experience in power plants, shops, construction and design. Now chief draftsman. Desires to make a change where there is an opportunity for advancement. I-302.

SALES ENGINEER. Technical graduate. Twelve years selling experience, especially government work. At present in charge of office of large machinery manufacturer. Desires similar position in New York. I-303

MECHANICAL ENGINEER. Long experience in England, Germany and United States in design and construction of passenger and freight cars and structural ironwork. Desires responsible position; able to take charge of men. Age 38, married. I-304.

MECHANICAL ENGINEER. Technical graduate. Ten years experience in designing, constructing and operating steam, electric and ice properties; five years in active charge. Desires position as general manager or construction manager for public utilities corporation or consulting engineering firm. At present employed. I-305

MECHANICAL ENGINEER or EXECUTIVE. Graduate M.E., age 40, Associate-Member. 10 years practical experience as executive. Desires change; would consider manager or superintendency for firm desiring man familiar with heavy machine design, up-to-date plant methods, efficiency, organization. I-306

EXECUTIVE in semi-executive capacity. Mechanical, electrical engineer; member both societies; age 41. Superintendent of operations largest City electricity-supply system, East; 18 years responsibility, design, construction, operation. Successful organizer, main and sub-station economies, boilers, stokers, smoke abatement, transmission and distribution, energy supply to railways. Best recommendations, employing corporations. I-307

PRODUCTION ENGINEER. Associate-Member, age 32. Broad experience factory and foundry operation, organization, production equipment, accounting and cost covering stamping, shaping, plating and finishing; also machine parts on interchangeable basis. Vicinity New York. I-308

SUPERINTENDENT, CHIEF ENGINEER or SALES ENGINEER. Experienced in design, installation, operation, and testing of complete power plant and pumping equipment, including engines, boilers, mechanical stokers, coal and ash-handling machinery, high-pressure piping and all accessories. Age 39. I-309

MECHANICAL ENGINEER. Graduate M.E. and E.E. Junior Member, age 33. Thorough, resourceful and energetic, desires position with large firm. In following position during past twelve years as engineer—operating, testing, draftsman, in charge of station, designing, resident engineer on construction, power engineer. At present employed as mechanical engineer. Location in or near New York. Salary $2500. I-310

ASSISTANT TO EXECUTIVE or SALES MANAGER. Member, technical graduate, age 36, desires change of position. Experience covers testing, research, designing and commercial engineering, in connection with steam turbines, turbo-blowers and centrifugal pumps, with responsible charge of men. New York City or eastern location preferred. I-311

MECHANICAL ENGINEER, Graduate Columbia University, 1915, desires to locate with manufacturing or engineering concern in or near New York. Two years power plant, shop and drafting room experience. Experienced in power plant testing, automatic machinery, installation and layout of machinery. At present employed in maintenance department of concern manufacturing automobile auxiliaries. I-312

SUCCESSFUL DESIGNER of automatic paper-box, bag, envelope machines, printing presses, etc., desires change. First class references. Salary not under $2500. I-313

MECHANICAL ENGINEER. Junior member. Technical graduate, age 25. Now employed in engineering work involving design, charge of installation of textile machinery, plant operation and management. Capable of taking initiative. Desires permanent position in aggressive company. I-314

MECHANICAL ENGINEER, 41, technical graduate. Extensive experience erecting, operating and testing power plant machinery; sales engineer; five years in charge of water works pumping plant, including supply and filtration. Desires change; will go anywhere in United States. I-315

MECHANICAL ENGINEER. Associate-Member, age 28, technical graduate. At present employed, but desires responsible position with manufacturing concern. Nine years experience in design, development and experimental work, as well as maintenance and operation of industrial plants. I-316

STEAM or EFFICIENCY ENGINEER. Graduate Cornell University, M.E., 1908. Broad executive experience. Would be glad to consider position as superintendent or assistant superintendent of employment. I-317

MECHANICAL ENGINEER. Junior Member, Graduate Cornell University, age 25. Three years practical experience in marine work, including ship construction and hydraulic dredge erection. Desires position with engineering firm or dredging contractor. Holds marine engineer's license. Excellent references. Salary $1200. I-318

MANAGER or CHIEF ENGINEER. Technical graduate. Now assistant manager large plant manufacturing steel freight and passenger cars, also munitions and army transportation equipment. 18 years experience; 5 years railroad shops; 3 years engine and boiler works; 10 years car designing and manufacture. Experienced in shop management, planning and efficiency, also in sales and purchasing. Desires change as plant manager or consulting engineer in above lines. I-319

INDUSTRIAL ENGINEER, Junior member. Two years experience as designer of heavy machinery; one year as draftsman of industrial plants; for the past year and a half with large industrial plant as industrial engineer. Familiar with cost accounting, scheduling, time study work, etc. Desires change. Location immaterial. I-320

JUNIOR MEMBER of Am.Soc.M.E. and S.A.E. Graduate M.E. Experienced in design of efficient high speed gasoline engines; definite knowledge of the many points of design that make for high speed, high power, and smooth running, with ability to apply this knowledge in developing designs. Position desired in some engine manufacturing concern, preferably one contemplating new designs. Location, Detroit, Mich. I-321

ENGINEER, with exceptional inventive talent, desires position requiring such ability. Cornell graduate, M.E. (having specialized in E.E.), with M.S. from Union College. One year experience at General Electric Co. and two years as university instructor in electrical engineering. At present assistant engineer of chemical factory. Salary a distinct object. I-322

MECHANICAL ENGINEER, age 31, technical training. At present employed in executive capacity; wide experience in combustion engineering and in design and operation of boiler plants. Desires position with boiler or stoker manufacturer, or with large plant as power efficiency engineer. Can produce results and is not afraid of responsibility. I-323

MANUFACTURERS REPRESENTATIVE OR SALES MANAGER. Consulting Engineer with New York Office, large industrial and engineering acquaintance in Eastern territory, wishes to add to representation on commission basis only. New York, New England States and New Jersey. I-324

COMBUSTION ENGINEER. Graduate, age 32. Ten years experience in handling boilers and mechanical stokers. Would like to take charge of power proposition where saving in fuel is desired. Can show good record. At present employed in large central station holding record for fuel company. I-325

EFFICIENCY ENGINEER. Graduate, M. E., University of Pennsylvania, age 28. Junior Member. Four years machine shop experience, eight months designing safety devices, jigs, fixtures, etc., one year connection in various phases in production department of manufacturing concern. Inventive inclination, has made several practical inventions. Wishes to specialize in labor-saving devices and improving machines in connection with efficiency work. Will start at $100 per month where advancement is assured. I-326

ACCESSIONS TO THE LIBRARY

A List of Books and Pamphlets Added During the Past Month to the Library of the Society and of the United Engineering Society, Engineering Societies Building, New York

ADDITIONS BY THE SOCIETY

BUILDING SINGLE PURPOSE LATHES IN A SINGLE PURPOSE SHOP, Ethan Viall. Reprinted from American Machinist, May 11, 1916. Gift of L. I. Yeomans.

CONNECTICUT SOCIETY OF CIVIL ENGINEERS. Papers and Transactions for 1915 and Proceedings of 32d Annual Meeting, 1916. *New Haven, 1916.* Gift of Society.

HENRY GANNETT, S. N. D. North. *1915.* Gift of C. W. Rice.

ILLINOIS SOCIETY OF ENGINEERS. 31st Annual Report, 1916. *Wheaton, 1916.* Gift of Society.

IS EQUAL JUSTICE POSSIBLE IN GOVERNMENT CONTRACTS? Wm. B. King. *Washington.* Gift of King & King.

LIQUEFYING AIR BY UTILIZING THE "JOULE-THOMSON EFFECT" AND MECHANICAL LIQUEFACTION BY AN EXPANSION ENGINE, J. F. Place. *Glen Ridge, N. J., 1916.* Gift of author.

NEW BRITAIN (CONN.) BOARD OF WATER COMMISSIONERS. 59th Annual Report, 1916. Gift of New Britain Board of Water Commissioners.

NEW ORLEANS. SEWERAGE AND WATER BOARD. 32d Semi-Annual Report. *New Orleans, 1915.* Gift of Sewerage and Water Board.

THE PLACE MECHANICAL PROCESS OF LIQUEFYING AIR AND THE SEPARATION OF LIQUID AIR INTO ITS CONSTITUENTS OXYGEN AND NITROGEN, J. F. Place. Gift of author.

REASONABLENESS AND LEGAL RIGHT OF THE "MINIMUM CHARGE" AND PUBLIC UTILITY SERVICES, S. S. Wyer. *Columbus, 1916.* Gift of author.

EL SISTEMA DE ALCANTARILLADO Y PAVIMENTACION DE LA CIUDAD DE LA HABANA. (Revista de la Sociedad Cubana de Ingenieros. Edicion Extraordinaria.) *Habana, 1916.* Gift of Sociedad Cubana de Ingenieros.

STURTEVANT WAR LETTERS FROM MEMBERS OF THE STAFF. *London, 1916.* Gift of Sturtevant Engineering Co., Ltd.

GIFT OF WATER POWER DEVELOPMENT ASSOCIATION

AN ANSWER TO GIFFORD PINCHOT. An open letter to the President of the U. S.

CRITICISMS OF THE SHIELDS BILL ANSWERED.

STEAM VS. WATER POWER. Factors that have hindered the building of water power plants and how such obstacles can and should be eliminated, by H. W. Buck.

WATER POWER AS A NATURAL RESOURCE. Editorial from The Outlook, Feb. 9, 1916.

TRADE CATALOGUES

DIAMOND POWER SPECIALTY CO. *Detroit, Mich.* Bull. 118. Insuluminum. *July 1916.*
FLANNERY BOLT CO. *Pittsburgh, Pa.* Staybolts. *July 1916.*
MACRAE'S BLUE BOOK CO. *New York City.* MacRae's Blue Book, vol. vii. *1916.*
PORTER, H. K. CO. *Pittsburgh, Pa.* Modern Compressed Air Locomotives, ed. 2. *1914.*
STANDARD PUMP & ENGINE CO. *Akron, Ohio.* Catalogue No. 16. Pumping units for water supply. *1916.*
WALWORTH MFG. CO. *Boston, Mass.* Walworth Log. *Aug. 1916.*

ADDITIONS BY THE UNITED ENGINEERING SOCIETY

AIRCRAFT IN WARFARE, F. W. Lanchester. *New York, 1916.*
AMERICAN CHEMICAL SOCIETY. Directory, revised to June 1, 1916. *1916.* Gift of Society.
THE AUTOMOBILE BOOK, C. E. Duryea and J. E. Homans. *New York, 1916.*
AXLES AND FORGINGS FOR STEAM AND ELECTRIC RAILWAY SERVICE. Standard axle designs and specifications. Carnegie Steel Company. *Pittsburgh, 1915.* Gift of Company.
BALANCING OF ENGINES, STEAM, GAS AND PETROL, Archibald Sharp. *New York, 1907.*
BIBLIOGRAPHIE DER DEUTSCHEN ZEITSCHRIFTEN LITERATUR. Band XXXVI B. *Leipzig, 1915.*
BLOCK SIGNAL AND INTERLOCKING SYSTEM OF THE SUBWAY DIVISION OF THE INTERBOROUGH RAPID TRANSIT COMPANY. Bulletin No. 21. Union Switch & Signal Company Gift of Union Switch & Signal Company.
BRITISH JOURNAL PHOTOGRAPHIC ALMANAC. 1883, 1889, 1892. Gift of Arthur Worischek.
CHART SHOWING PRICES OF NON-FERROUS METALS FOR 1898-MARCH 1916. Gift of Daily Iron Trade.
CHRONOLOGY OF AVIATION, Hudson Maxim and W. J. Hammer. *New York, 1912.* Gift of Aeronautical Society.
COAL, ITS ECONOMICAL AND SMOKELESS COMBUSTION, J. F. Cosgrove. *Philadelphia, 1916.*
COAL MINERS' POCKETBOOK. ed. 11. *New York, 1916.*
COKE OVEN ACCIDENTS IN THE UNITED STATES DURING THE CALENDAR YEAR 1915. Technical paper 151, U. S. Bureau of Mines. *Washington, 1916.*
CONCRETE ON THE FARM AND IN THE SHOP, H. Colin Campbell. *New York, 1916.*
DAMS AND WEIRS. W. G. Bligh. *Chicago, 1915.*
DESCRIPTION OF EXHIBITS OF UNITED STATES STEEL CORPORATION AND SUBSIDIARY COMPANIES. Gift of Carnegie Steel Company.
EDDYSTONE LIGHTHOUSE, NARRATIVE OF THE BUILDING AND A DESCRIPTION OF THE CONSTRUCTION, John Smeaton. ed. 2. *London, 1813.* Gift of W. L. Harkness.
EFFECTS OF TEMPERATURE AND PRESSURE ON THE EXPLOSIBILITY OF METHANE AIR MIXTURES. U. S. Bureau of Mines. Technical paper 121. *Washington, 1916.*
THE ENGINEER IN WAR, P. S. Bond. *New York, 1916.*
ENGINEER'S YEAR BOOK, 1916, H. R. Kempe. *London, 1916.*
FEDERAL REGISTRATION SERVICE OF THE UNITED STATES; ITS DEVELOPMENT, PROBLEMS AND DEFECTS. U. S. Bureau of Census. *Washington, 1916.*
GEAR BLANKS AND MISCELLANEOUS CIRCULAR SECTIONS. ed. 3. *Pittsburgh, 1916.* Gift of Carnegie Steel Company.
GEOLOGY AND GROUND WATERS OF NORTHEASTERN ARKANSAS. U. S. Geological Survey. Water Supply Paper 399. *Washington, 1916.*
HISTORY AND HANDBOOK OF PHOTOGRAPHY. Edited by J. Thomson. *New York, 1877.* Gift of Arthur Worischek.
HYDRAULICS AND ITS APPLICATIONS, A. H. Gibson. *New York, 1915.*
INDIA. Geological Survey. Contents and Index of the Memoirs. vols. xxi-xxxv, 1884-1911. *Calcutta, 1916.*
INDUSTRIAL ACCIDENT PREVENTION, D. S. Beyer. *Boston-New York, 1916.*
LA INDUSTRIA MINERA DE MEXICO, Fernando Gonzalez and others. nos. 1-6. *Mexico, 1911.*
INSTITUTION OF MECHANICAL ENGINEERS. List of members, March 1916. *London, 1916.*
IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY AND CITY AND GUILDS OF LONDON INSTITUTE. Prospectus of the City and Guilds, June 1916. *London, 1916.* Gift of Imperial College of Science, etc.
INTERNATIONAL ENGINEERING CONGRESS, 1915. Transactions. vol. iv. Railway Engineering. *San Francisco, 1916.*
INTERNATIONAL ENGINEERING CONGRESS. vol. v. Materials of Engineering Construction. *San Francisco, 1916.*
INVESTIGATION OF THE PEAT BOGS AND PEAT INDUSTRY OF CANADA. 1913-14. Bulletin No. 11, Canada, Dept. of Mines. *Ottawa, 1915.*
LATHES: THEIR CONSTRUCTION AND OPERATION, G. W. Burley. *London, 1915.*
LIMESTONES AND MARLS OF THE COASTAL PLAIN OF GEORGIA. A Report. Bulletin 21, Georgia Geological Survey. *Atlanta, 1916.*
LOGARITHMISCH-TRIGONOMETRISCHE TAFELN, Georg Vega. Band 1-2. *Leipzig, 1797.*
MARYLAND GEOLOGICAL SURVEY. Upper Cretaceous. 2 vols. Text and plates. *Baltimore, 1916.*. Gift of Survey.
MECHANICAL TECHNOLOGY, G. F. Charnock. *New York, 1915.*
MICHIGAN ENGINEERING SOCIETY. Proceedings, vol. 34, 1916. *Kalamazoo, 1916.* Gift of Society.
MICROMOTION STUDIES APPLIED TO EDUCATION, A. A. Douglass and W. L. Dealey. Reprinted from the Pedagogical Seminary. June, 1916. Gift of Frank Gilbreth.
MINE SAMPLING AND VALUEING, C. S. Herzig. *San Francisco, 1914.*
MINNEAPOLIS-ST. PAUL FOLIO. U. S. Geological Survey, Folio 201. *Washington, 1916.*
MOODY'S MANUAL OF RAILROADS AND CORPORATION SECURITIES, 1916. Vol. II. Industrial and Public Utility Section. *New York, 1916.*
MOODY'S MANUAL. Complete list of securities maturing. Vol. II. June 1st, 1916-June 30, 1918. Arranged chronologically. *New York, 1916.* Gift of Moody Manual Company.
NATIONAL FIRE PROTECTION ASSOCIATION. Proceedings of 20th Annual Meeting, 1916. *Chicago, 1916.* Gift of Association.
NAVIGATION; NOTES AND EXAMPLES, S. F. Card. *London, 1916.*
NOTRE 75, PAR UN ARTILLEUR. *Paris, 1915.*
PETROLEUM WITHDRAWALS AND RESTORATIONS AFFECTING THE PUBLIC DOMAIN. U. S. Geological Survey. Bulletin 623. *Washington, 1916.*
POOR'S MANUAL OF PUBLIC UTILITIES. 1916. *New York, 1916.*
PRACTICAL DESIGN OF STEEL FRAMED SHEDS, A. S. Spencer. *New York, 1915.*
PRINCIPLES OF ELECTRICAL DESIGN. D. C. AND A. C. GENERATORS, Alfred Still. *New York, 1916.*
QUANTITY OF GASOLINE NECESSARY TO PRODUCE EXPLOSIVE CONDITIONS IN SEWERS. U. S. Bureau of Mines. Technical Paper 117. *Washington, 1916.*
RAILWAY PROBLEMS OF THE DAY. WHAT THEY MEAN TO MANUFACTURERS. Address of Chas. J. Graham. May 17, 1916. Gift of Bureau of Railway Economics.
RESULTS OF MAGNETIC OBERVATIONS MADE BY THE UNITED STATES COAST AND GEODETIC SURVEY IN 1915. U. S. Coast and Geodetic Survey Special Publication No. 36. *Washington, 1916.*
RESULTS OF OBSERVATIONS MADE AT THE UNITED STATES COAST AND GEODETIC SURVEY MAGNETIC OBSERVATORY AT VIEQUES, PORTO RICO, 1913-1914. U. S. Coast and Geodetic Survey, Serial No. 33. *Washington, 1916.*

GIFT OF THE HILL PUBLISHING COMPANY

A good collection of twenty-nine text books.

GIFT OF ARTHUR WORISCHEK

Amiot, A. Eléments de Géométrie. ed. 6. *Paris, 1860.*
Bayley, Thos. A Pocket-book for chemists. ed. 4. *1886.*
Bolas, Thos.: Tallent, A. A. K. & Senior, E. Handbook of photography in colors. *1900.*
Duchochois, P. C. Industrial Photography. *1901.*
Elementary Course in Dry Plate Photography. *1882.*
Harrison, W. J. History of Photography. *1887.*
Hasluck, P. N. Knotting, and Splicing ropes and cordage. *1913.*
Heather, J. F. Treatise on Mathematical Instruments. ed. 7. *1864.*
Hearn, C. W. Practical Printer. *1874.*
Hinton, A. H. Handbook of Illustration.
Pitman's Commercial Terms and Phrases in Five Languages.
Price, H. C. How to make pictures. *1882.*
Robinson, H. P. and Abney, Capt. Art and practice of silver printing.
Wall, E. J. Dictionary of photography. *1889.*
Wireless Association of America. First Annual Official Wireless Blue Book, *May 1909.*

TRADE CATALOGUES

THE ALEXANDER MILBURN CO. *Baltimore, Md.* Milburn oxy?acetylene welding and cutting apparatus.
AMERICAN BLOWER CO. *Detroit, Mich.* Sirocco Service-Ventura Number.
INGERSOLL-RAND COMPANY. *New York, N. Y.* Form No. 4120. Leyner-Ingersoll Water Drills. *Dec. 1915.*
IVANHOE-REGENT WORKS. *Cleveland, O.* The Hunchman. *June 1916.*
PYRENE MANUFACTURING CO. *New York, N. Y.* The Firefly. *June-July 1916.*
UNDER-FEED STOKER COMPANY OF AMERICA. *Chicago, Ill.* Publicity Magazine. *June 1916.*

ENGINEERING SURVEY

A Review of Engineering Publications in All Languages. All the leading periodicals of the engineering world, embracing over 1000 different publications, are received at the Library. These are systematically examined for review each month in the Survey.

SUBJECTS OF ABSTRACTS

ARRANGED IN THE ORDER OF THEIR APPEARANCE IN THE SURVEY.

AEROPLANE ACCIDENTS.
AIR GUSTS.
SCIENTIFIC RESEARCH IN AEROPLANE CONSTRUCTION.
RESEARCH DEPARTMENT OF THE CURTISS COMPANY.
VULCANIZATION OF PLANTATION PARA RUBBER.
NITROGEN CONTENT AND CURE OF RUBBER.
PROTEIN DECOMPOSITION AND CURE OF RUBBER.
CURE OF SHEET RUBBER.
TOOL STEEL HARDENING AND GRINDING.
NORMALIZING OF TOOL STEEL.
FUNGUS GROWTH ON WOOD.
FIRE RETARDENTS.
CONCRETE, SOME PROPERTIES OF.
AMERICAN PETROLEUM OILS, DENSITY.
AMERICAN PETROLEUM OILS, THERMAL EXPANSION.
PRE-HEATED BLAST CUPOLA.
CASTING 8 IN. H.E. SHELL INGOTS.
FORGING ROUGH 8 IN. H.E. SHELLS.
PEAT AS FUEL.
GERMAN STEAM PLANT USING PEAT FUEL.
CYCLOIDAL CURVE LAW OF DISTRIBUTION OF VELOCITIES IN FLOW OF WATER IN PIPES.
ANTI-FRICTION BEARINGS IN AXLE GENERATORS.
ANTI-FRICTION BEARINGS ON BAGGAGE TRUCKS.
ANTI-FRICTION BEARINGS ON TRUCKS IN CREOSOTING PLANTS.
ALUMINUM WELDING.
DRAWING METAL BY HYDRAULIC METHOD.
HYDRAULIC PRESS SYSTEM FOR SHELL MAKING.
THERMALENE PRODUCTION AND PROPERTIES.
THERMALENE WELDING TORCH.
AEROPLANE CYLINDERS, MACHINING.
HYDRAULIC AND STEAM-HYDRAULIC FORGING OF SHELLS COMPARED.
STEAM-HYDRAULIC SHELL FORGING IN RUSSIA, TIME TABLE.
CHART, ENGINE FRAME LOADS.
ACCELERATING CHARACTERISTICS, CENTRIFUGAL PUMPS AND FANS.
THEORY OF ELASTICITY.
UNSYMMETRICAL RIVETED JOINTS, EFFICIENCY.
PLASTIC FLOW PHENOMENA.
PLASTIC FLOW OF STEEL AND CLAY.
COKE-OVEN GAS POWER PLANT.
COKE-OVEN GAS, CLEANING.
PRE-IGNITION THROUGH SULPHUR IN GAS ENGINES.
PRIME MOVERS FOR ISOLATED PLANTS.
INDICATOR DIAGRAMS FROM A COMPOUND CORLISS.
UNIFORM BOILER LAWS IN CANADA.
STEAM ECONOMIES ON FRENCH RAILROADS.
MALLEABLE AND CAST STEEL TESTING.
FIRE-BRICK TESTING.
HARDNESS TESTING OF NON-FERROUS METALS.
CHARTS.

There is in this issue of the Engineering Survey an abstract of a description of the Engineering Department of the Curtiss Aeroplane and Motor Corporation plant at Buffalo, N. Y. To many it will come as a great surprise. The industry was created less than five years ago, as the entire previous period of heavier-than-air flying was devoted to experimental work and exhibition flights exclusively. And nevertheless we find that the engineering department only of the Curtiss works employs 150 men, and we find further that the thoroughness of designing and construction in the manufacture of aeroplanes equals if not surpasses that in many older and far more established branches of the mechanical art.

In this connection, particular attention is called to the illustration on page 749, reproducing a working blueprint of an aeroplane wing. The data presented there are of no particular interest as such, but it is believed that engineers will be interested to note how carefully all the details of construction are worked out and how far aeroplane building has passed from the stage of guesswork and cut-and-try methods of the early days, "early days" which are, however, probably less than three years ago.

THIS MONTH'S ARTICLES

Lieutenant R. C. Saufley discusses the causes of aeroplane accidents with particular reference to the action of gusts. He gives also an interesting summing up of the present situation with respect to the position of the aerial branch of the Navy Service: "The developments of the last twelve months have left no doubt as to the naval advantage to be gained from the use of aircraft. . . . Ignorance, not unbelief, is our problem."

In the section Engineering Materials will be found the continuation of an abstract of the report on important experiments on the vulcanization of plantation Para rubber, in which the writer determines the cause of variability of curing and establishes its connection with the nitrogen content of the latex.

In the same section will be found an abstract of the report presented by the Tool Research Committee to the Manchester Association of Engineers. The most important conclusions to which their experiments led are that some of the tools showed a decided deterioration on regrinding only after a failure, which is contrary to general belief. Further, it was found that high speed steel is not injured by repeated heating at high temperature, such as that required for hardening, and that normalizing does not materially improve lathe tools.

There are two articles on the behavior of wood, one discussing the fungus growth on untreated wood and ties, and another the efficiency of fire retardents with special reference to their use on roof shingles. The last of these articles is of particular interest as it presents data of an experimental investigation carried out in a systematic manner.

From a scientific paper of the U. S. Bureau of Standards are abstracted some data on the strength and other properties of concrete as affected by the constituent materials and method of preparation. In the same section will be found an advance abstract of a Technologic Paper on the density and thermal expansion of American petroleum oils. Through the courtesy of Dr. S. W. Stratton, Director of the Bureau of Standards. The Journal has been accorded the valuable privilege of receiving advance notices of Technologic Papers published by the Bureau. Abstracts of these papers will in future be reported in the Engineering Survey at the earliest opportunity.

The casting of 8-in. H.E. shell ingots is discussed in the section Foundry.

B. F. Haanel, in a paper before the American Peat Society, considers the value of peat fuel as compared with coke, and among other things presents some interesting data on a large steam power plant (over 5000 h.p.) designed for the exclusive use of peat fuel in Germany. From the paper it appears that peat fuel can be used for power generation only where the

strictest economies are introduced in the manufacture and use of the fuel, and where further no other fuel is readily available.

The law of distribution of velocities in the flow of water in pipes is expressed by a cycloidal curve by Moignié, in a French official periodical.

Several letters and articles on the use of anti-friction bearings in railway axle generator service are reported from the *Railway Electrical Engineer*.

In the section Machine Shop attention is called to the several articles on forging, referring mainly to forging blanks for large shells either hydraulically or by steam presses. In the same section will be found an abstract taken from the *American Machinist* on the production, properties and use of thermalene, a new gas designed to take the place of acetylene for purposes of welding and metal cutting.

A chart for determining engine frame loads is reproduced from *Machinery* in the section Mechanics. In the same section will be found a brief discussion of the accelerating characteristics of centrifugal pumps and fans.

From the *London Philosophical Magazine* are briefly abstracted the main points of a very interesting mathematical discussion of some of the fundamental problems in the theory of elasticity, in particular those of elastic equilibrium under certain given conditions.

R. N. Blackburn's discussion of the comparative efficiency of symmetrical and unsymmetrical joints brings out the important distinction between apparent efficiency calculated from formulae under certain assumptions, and the actual efficiency of a riveted joint, such as would be determined by measurement. There ought not to be any difference between the two efficiencies if the assumptions on which the formula is based always held good in actual practice, and Mr. Blackburn claims that this is not the case. He also expresses the opinion that as far as the stresses in an unsymmetrical joint are concerned, the bending action is of more importance than the direct stress due to the pull on the plate.

The description of a plant for the production of power from coke-oven gas is abstracted from a British periodical. It contains some data on the purification of the gas, especially on the elimination of sulphur. The author calls attention to the comparatively little known fact that the presence of sulphur in the gas may cause pre-ignition of the charge during the compression stroke. Another point of interest is the fact that, by regular attention to exhaust analysis and methods of driving the engines, the gas consumption per month on the same load was reduced from 15 million cu. ft. to 12½ million cu. ft.

From tests made upon the high and intermediate cylinders of a triple-expansion Corliss engine, Prof. Victor R. Gage comes to the conclusion that the logarithmic analysis of the indicator diagrams cannot be applied under all conditions. On the other hand, he shows that the point of thermal equilibrium and the general behavior of the steam during expansion can be readily shown by means of the temperature-entropy diagram.

The application of the Brinnell method for regulating methods of manufacture of non-ferrous metal product is reported in some detail in an abstract of an article by Hugo Friedmann. He points out several useful applications of the hardness test. For example, for discovering whether the entire piece cooled at the same speed, or for determining in certain cases the properties of the metal at different distances from the surface. Likewise, for example, in the case of aluminum, a hardness test enables to determine whether the hardness of the metal is due to its chemical composition or to the mechanical treatment to which it has been submitted.

That firebricks tend to group themselves with respect to most of their mechanical properties according to their density is a practical conclusion arrived at from a number of tests. These tests also covered the subjects of spalling, slagging and compression strength of fire bricks.

Aeronautics

AEROPLANE ACCIDENTS: CAUSES AND REMEDIES,

Lieut. R. C. Saufley, U. S. Navy

The author attributes aeroplane accidents to three general causes, namely, (1) air conditions, (2) material, (3) personal error. In the first stages of aeroplane construction, when the factor of safety was small and the machines were slow and underpowered, casualties from causes (1) and (2) were frequent.

As regards air conditions, gust action may be classified as one of the great causes of aeroplane accidents. The general effect of gusts upon aeroplanes depends on the direction. Accidents due to *rear gusts* occur because the aeroplane flies suddenly into a region of air being accelerated in the direction of the machine's path. Were the air accelerations strong enough, the direction of air flowing through the wings would be momentarily reversed and the machine would drop precipitously. Fortunately, there are no records of air currents being accelerated to such an extent, as experiments have shown few air accelerations beyond 15 miles. What ordinarily happens in case of the real gust is that the velocity relative to the aeroplane is momentarily reduced and, the machine's inertia preventing an immediate absorption of the gust's speed, lift and control are lost. It must be said, however, that actually the gust cannot overtake an aeroplane, and the term "rear gust" is therefore a misnomer.

The author endeavors to explain the effect of a rear gust upon an aeroplane by assuming that the machine is sustained in normal flight, disregarding the consideration of air velocity. With this explanation, any variation in the conduct of the machine must be due to a variation of *gravity relative to the air*. This latter term has the following meaning: When a machine is being sustained in undisturbed air, *i.e.*, air whose velocity is constant, "gravity relative to the air" and "absolute gravity" are the same, but if the supporting medium is suddenly accelerated, the machine's equilibrium must be momentarily adjusted to the resultant of the two accelerations, gravity and the gust. This resultant is the new "gravity relative to the air," the direction of which is perpendicular to the air only when the air acceleration or gust is directly outward or downward.

While fatalities due to *downward gusts* have been less frequent than those due to rear gusts, this is only because few flights were attempted when this sort of gust was prevalent. Actually, the downward gust is doubly dangerous as compared with the rear gust, both on account of the dangerous absolute path of the machine and its critical incidence to the air when the gust is past. The downward gust accounts for the phenomenon observed in very disturbed air when the machine seems to be struck with such violence as to make a small wrench and pliers jump from the pilot's seat. To the downward gust, likewise, may be attributed many stalls that are ordinarily assumed to have arisen from other causes, and it has sometimes caused the smash of machines when they have been thrown bodily to the earth just after making a "getaway."

The danger of the *head gust* is due to the fact that its en-

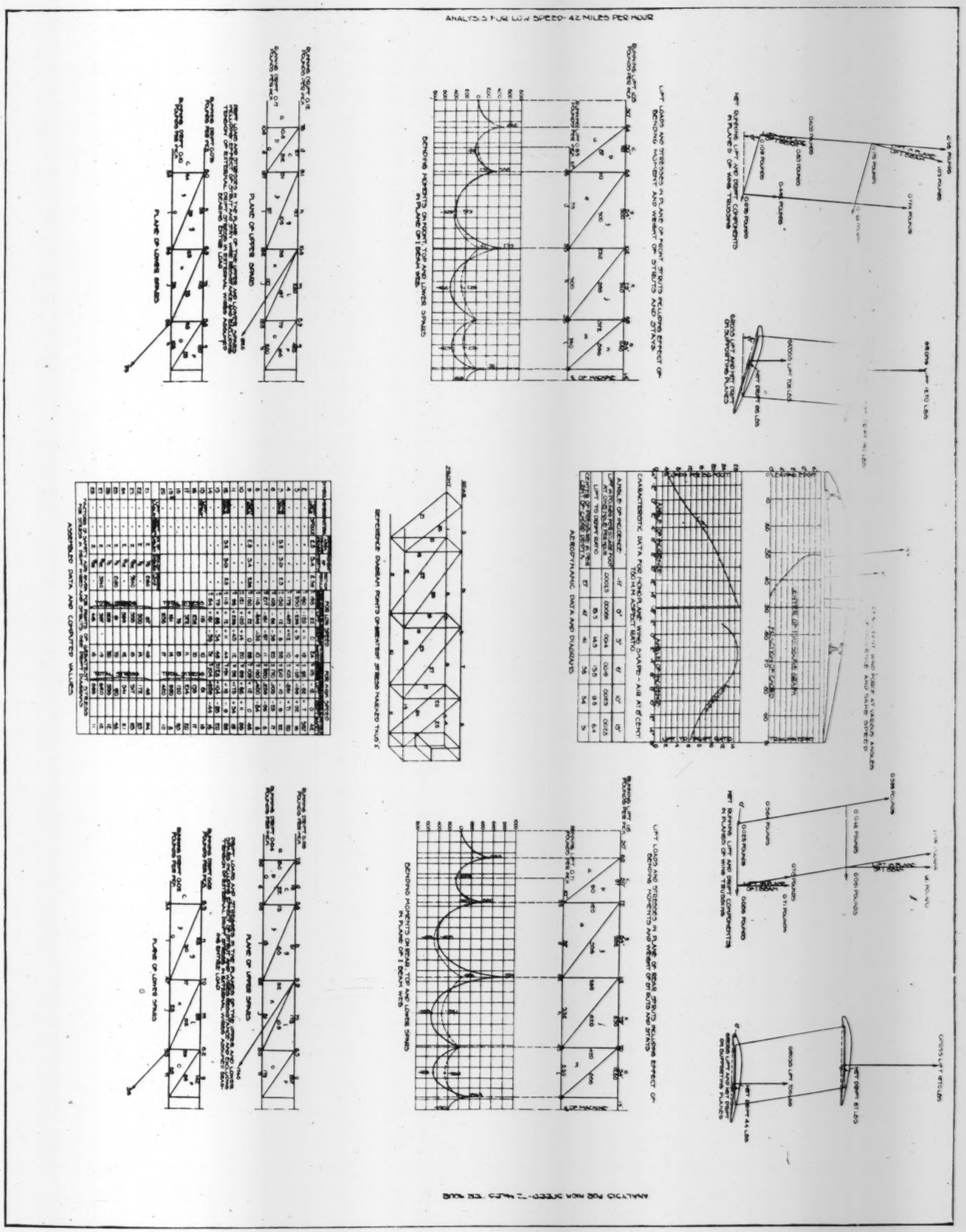


FIG. 1 A COMPLETE STRESS ANALYSIS IS MADE OF THE WING FRAMING OF EACH TYPE OF MACHINE MADE BY THE CURTISS COMPANY

As shown in the above diagrams, the results are arranged on one sheet in convenient form, and consist of the following: 1. Shape of wing curve used, and its aeridynamic properties. 2. Diagram showing the lift and drift components in the planes of the wing trussing. 3. Diagrams of the wing framing showing the lift and drift stresses. 4. Diagram showing the bending moments in the wing spars. 5. A summary giving the area, moment of inertia, section modulus, stresses and factor of safety of each member of the wing framing. 6. A reference diagram to accompany the summary.

counter momentarily increases the velocity of air under the lifting surfaces, thereby increasing the lift under the machine. The latter immediately starts to climb. When the gust is passed the machine, being pointed upward, retakes the undisturbed air at a larger angle than it can fly; hence a stall ensues.

Accidents due to ruptures of material have unquestionably been frequent, but a steady and rapid improvement in material is gradually reducing them. As regards ruptures due to propellers, the author calls attention to the fact that tractor-type military aeroplanes appear to suffer a good deal less than the pusher type.

There are many cases where ruptures of the gasoline tank have forced landings. Likewise several instances where backfires from the carburetor have caught in the drip from a gasoline leak and burned the machine completely. In one case the afterpart of the gasoline tank broke off bodily and struck the propeller.

The accidents due to the personnel are discussed in detail. Reviewing the whole situation, the writer comes to the following conclusion: "The developments of the last twelve months have left no doubt as to the naval advantage to be gained from the use of aircraft. The question now confronting us is not whether aircraft can accomplish their mission, but how soon and how well can the navy acquire their use. The seaplane is but a weapon, and, following the rule of weapons, it is dangerous to him who handles it without interest or without care. Ignorance, not unbelief, is our problem." (*United States Naval Institute Proceedings,* vol. 42, no. 164, p. 1117, July-August, 1916, 19 pp., 6 figs. *gtp.*)

Scientific Research in Aeroplane Construction at the Factory of the Curtiss Aeroplane and Motor Corporation

The Engineering Department of the Curtiss Aeroplane and Motor Corporation at Buffalo comprises over one hundred and fifty men and occupies a floor space of 30,000 sq. ft. in the factory, together with additional testing laboratories outside of the factory.

This department consists of four main divisions: First, the Motor Designing and Testing Department; second, the Aeroplane Designing Department; third, the Aeroplane Development Department; fourth, the Research and Test Department.

Some of the divisions of the last department are of particular interest. The mathematical division forms a very important part of it. Before commencing the working drawings of a new type of aeroplane, the Designing Department submits to the Mathematical Department the preliminary sketch of the proposed machine and secures an estimate of its efficiency and of the factors of safety of its various structural members. The working drawings are then made consistent with these estimates. As the design becomes more fully crystallized, the Mathematical Department makes a complete graphical analysis of the stresses and factors of safety in all the principal members of the aeroplane. It furthermore computes and presents in graphical form the air resistance of the proposed craft, the power required to drive it, the rate of climb, the range of speed and corresponding angles of incidence, the gliding angle, the conditions of stability, etc.

In the Structure Testing Laboratory, among other things, experiments are made to determine the mass distribution, strength and factor of safety of all the structural parts and of the assembled machine. For example, the moment of inertia of the entire machine loaded for flight is determined by suspending the machine from the ceiling of the laboratory and allowing it to vibrate about its three principal axes.

For determining the aerodynamical properties of full-scale aeroplanes and their structural parts, a special laboratory, 30 by 60 ft., has been set apart and provided with apparatus for generating a uniform current of air. A wind tunnel of the latest British pattern produces a uniform stream of air, 4 ft. sq. in section and 30 miles per hour in velocity. In this current various models are supported from the sheltered arm of a wind balance, which has its weighing beams outside the tunnel, and is adapted to measure accurately the lift of the model, the head resistance and the center of pressure at all different angles of incidence. The speed of the air is uniform to less than one per cent at all parts of the cross-section of the tunnel. The direction of the flow is parallel to the walls of the tunnel truly to a small fraction of a degree.

In developing a new type of propeller, a tentative draft is first made by the Propeller Division on a drawing board and subjected to mathematical analysis. From the given dimensions and speed of a propeller are calculated the thrust, torque and efficiency of each section of the blade, and from these results are computed the aggregate thrust, torque, thrust power, torque power and efficiency of the whole propeller. When these properties are finally made satisfactory, accurate scale drawings and blueprints are made and from these templates are constructed for use in the propeller factory.

Simultaneously, estimates are made of the structural strength of the blade and of the internal stresses due to centrifugal force and air pressure. From the resultant stresses within the blade, and from the predetermined tensile and compressive splitting strength of the wood the factor of speed of the blade is computed. In designing the sheet-metal propeller tips, the centrifugal force of each portion of the sheathing is computed and measurements are made of the resistance and strength of the rivets or nails which secure the metal to the wooden propeller tip.

An interesting section of the laboratory is the Photographic Studio. For many years the Curtiss Company has made and preserved photographs showing the development of all its important devices and constructions, and as far as possible the performance of its various types of aircraft. Experience has shown that many important details of structural development which have escaped the memory of the entire force at the factory are clearly disclosed in the photographs, both still and moving-picture. These photographs have, therefore, an engineering as well as commercial and historical value.

The Engine Testing Laboratory was planned on a very large scale. There are two large dynamometers, each of 300-h.p. rated capacity at from 1500 to 3500 r.p.m., and with standard overload rating. A feature of these dynamometers to which attention is called is the extension of both ends of the shaft instead of only one end as in former installations. The double end arrangement is claimed to be of advantage as it permits one engine to be set up and prepared for running while the test is in progress on another engine connected to the other end of the dynamometer shaft. The special test plates, engine support pedestals and gasoline support column are so arranged that all connections except the water inlet and outlet can be completed beforehand and moved up with the engine.

Fig. 1, showing a complete stress analysis of the wing framing, is here reproduced to demonstrate the thoroughness with which the engineering features are handled in modern aeroplane construction. (*Aerial Age Weekly,* vol. 3, no. 19, p. 562, July 24, 1916, 7 pp., 11 figs. *d.*)

Engineering Materials

VULCANIZATION EXPERIMENTS ON PLANTATION PARA RUBBER: THE CAUSE OF VARIABILITY AND SOME CONTRIBUTING FACTORS, B. J. Eaton and J. Grantham

Continuation of the paper reported in THE JOURNAL (December, 1915, p. 725.)

Previous experiments have led the writers to the belief that the primary cause of variability in the rate of cure of plantation Para rubber lay in the accelerating action of a small quantity of some substance existing in the latex or produced subsequently in the raw rubber from some constituent present in the latex. The present series of experiments has, therefore, been directed to ascertain the nature of this substance and its behavior under different treatments. The writers have been able to isolate or prepare a substance or substances from the latex serum to which acceleration in rate of cure can be attributed, and have obtained evidence of the presence of a second substance which also has a similar effect. Hence it becomes possible, by adopting certain rigid methods of preparation of raw rubber, to obtain uniformity in rate of cure and also, if desired, to prepare various types of raw rubber having specific rates of cure.

Because of lack of space only a summary of this important investigation can be here reported.

1 The experiments and results contained in Part 1 of this paper show that one factor which causes variability in respect to rate of cure in plantation Para rubber is produced during the first six days after coagulation, and that the change which takes place in the coagulum is progressive during this period, while after this period no further change under ordinary conditions takes place.

2 The action of antiseptics, such as formalin, also heat and cold, are shown to inhibit this change, while soaking of the fresh coagulum in running water considerably retards the rate of cure.

3 The action of formalin is also shown to be partly though not to any great extent an action on the accelerating agent after its formation.

4 Experiments on the cold storage of freshly coagulated rubber show that while the change which produces rapidity of cure is inhibited as long as the coagulum remains in cold storage, if the rubber is removed again and allowed to remain, without machining, for a further period (13 days or possibly less) at ordinary atmospheric temperatures (about 85 deg. fahr. in the Federated Malay States), rapidity of cure is again brought about.

5 All the experiments in Part 1 suggest that the change which produces rapidity of cure in the rubber is caused by biological agencies, *i.e.*, micro-organisms entering the latex after collection and remaining in the coagulum, and that the change is probably a decomposition of the protein or nitrogenous substances present in the coagulum producing an accelerating agent which is a decomposition product of the proteins.

6 The experiments in Part 2 on the addition to slow-curing rubbers of various proteins and nitrogenous substances and their decomposition products, including the proteins from latex serum, decomposed by suitable methods after separation from the serum, confirm the conclusions arrived at from the experimental evidence contained in Part 1, and show that the original proteins have little or no effect under the conditions employed, while the decomposed proteins have a marked effect.

7 Experiments with undecomposed evaporated serum, after separation of the proteins coagulated by heat, suggest the presence of a second factor which accelerates the rate of cure, and due to some substance originally present in the latex.

8 In the case of our so-called "slab" rubbers possibly both factors are responsible for the acceleration in rate of cure, and it would appear that the second factor may be responsible for the actual superior tensile properties of the rubber; some evidence to this effect is contained in the comparatively poor quality of the rubbers to which the protein decomposition product has been added, in which the second factor has been removed, and also in the good quality in the case of the evaporated latex samples and the rubber to which the evaporated serum has been added. Further experiments are, however, necessary to confirm this.

9 Experiments with evaporated latex, which contains all the serum constituents and is dried sufficiently rapidly to prevent decomposition of the proteins, also confirm the presence of this second factor.

10 The nitrogen figures given in Part 3, still further confirm the decomposition theory, *i.e.*, the production of some substance from the protein which accelerates the rate of cure, the nitrogenous portion which becomes soluble in water and is removed on crepeing being non-essential. On the other hand, the high nitrogen content in rapidly curing rubbers produced by evaporation of the latex without decomposition of the protein, again confirms the evidence obtained as to a second factor which is probably of a non-nitrogenous nature.

11 These experiments and results also show why it has not been possible hitherto to connect the nitrogen content of a rubber with its rate of cure, since a rapidly curing rubber may have either a low or high nitrogen content, and indicate how previous workers have gone astray or not gone sufficiently far in their investigations in connection with the protein or nitrogenous constituents of latex and rubber.

12 Many other experiments on nearly 1000 samples of rubber which are not included in this present paper all confirm the above results and conclusions.

13 A further investigation is now being made as to the exact nature of the protein decomposition product which accelerates the rate of cure, and as to the nature of the second factor responsible for acceleration, together with the numerous subsidiary factors which influence rate of cure, a number of which have already been investigated.

Since this paper has been completed, the writers have found that the protein left in sheets of average thickness can be decomposed and so produce a more rapidly curing sheet rubber by simply rolling up the sheets after machining in order to retain a sufficient moisture content for the basterial decomposition, which demonstrates that the rapidity of cure of the so-called "slab" rubber is largely due to the decomposition of protein normally retained by the rubber even after rolling to sheet form. These results also show the importance of the rate of drying during early stages as a factor in the preparation of sheet rubber, in order to have a uniform rate of cure. (*Journal of the Society of Chemical Industry*, vol. 35, no. 13, p. 715, July 15, 1916, 14 pp., *etA*)

TOOL-STEEL RESEARCH

Abstract of an interim report presented by Mr. Dempster Smith on behalf of the Tool Research Committee of the Manchester Association of Engineers.

This Committee was appointed in 1914 to undertake tests in the heat treatment of tool steel to ascertain whether uniformity in results could be obtained in successive trials made under identical conditions.

The operations of the Committee included tests made to ascertain whether a tool that has failed in use is less serviceable after being simply reground, and if so whether heat treatment restores the tool to its original vitality. The report includes the opinion of several experts on the question of heat treatment and the possibility of obtaining uniform results, and deals with the effect due to carrying heat treatment to different stages, normalizing and tempering.

It was decided at the outset that only one grade of tool steel be used. The tools selected had a nose radius of 0.5 in., a cutting angle of 70 deg. in a plane at 45 deg. to the length of the tool, which is equivalent to a front and side top rake of 14.5 deg., and a clearance angle of 6 deg. The cutting speed was selected to be such as would give a 20-min. life to the tool when heat-treated according to the steelmaker's instructions. The heat treatment recommended by the maker was to raise the temperature slowly to about 800 deg. cent. and then quickly to 1275 deg.

For the cutting test the trials were made on a medium steel bar and without a lubricant. In all cases the test was continued until the tool failed. The results showed a slight improvement on rehardening tool No. 1 and the improvement in one case but not in another for tool No. 5. Tools Nos. 2 and 4 showed a decided deterioration on regrinding only after a failure. This result was contrary to expectations, it being generally understood that the performance of a tool improves after the first failure.

Another idea of which the credibility has been shaken by the present tests is that high-speed steel is injured by repeated heating to a high temperature such as that required for hardening (some engineers for this reason prefer to harden turning tools in the smith's hearth where the heat is concentrated at the nose of the tool). The result of these trials showed that two rehardenings do not appreciably impair the cutting quality of the steel.

Tools Nos. 2 and 4 were then normalized, reground, hardened and tested again. The normalizing process consisted in heating the tool slowly (about ten minutes) to a dull cherry red (800 deg. cent.), placing the tool in hot cinders, and allowing it to cool. The normalizing preceded the grinding and hardening processes. The results were in neither case equal to those obtained by these tools when new, and it could not be found generally that any benefit had accrued from normalizing. It was concluded that in the case of formed cutters which had been unequally strained in machining or in annealing, the normalizing process might tend to eliminate these strains, but it would hardly have any pronounced effect on a lathe tool which has not been cracked, and which has been carefully forged and not hammered after the temperature has fallen below a cherry red (*i.e.*, about 900 deg. cent.).

One other conclusion arrived at is that with freshly forged tools, hardened as stated and tested under identical conditions, it was possible to obtain results within 5 per cent of the mean and within an extreme difference of 9 per cent.

Among other things, the report contains advices from an authority on the heat treatment of tool steel.

As the methods of hardening adopted by experts show great variations as to furnace temperature and duration of treatment, the data collected in this report (not abstracted here) may be likewise of interest. (*The Foundry Trade Journal*, vol. 18, no. 175, p. 370, July, 1916, 2 pp. *eA.*)

FUNGI WHICH GROW ON UNTREATED TIES OR UNTREATED WOOD, H. von Schrenk

Discussion of the Efficiency of Wood Treatment.

One of the conditions of wood treatment, which is often lost sight of, is that the material must be still in good condition before treatment and it is necessary to use the most rigid methods in handling such material before it is actually treated.

The only safe basis upon which one can rely in trying to tell the actual condition of wood is to saw off the ends of a considerable number of ties. A simple inspection of the back of a log does not tell anything.

Another important point in connection with the problem of the growth of fungi on treated wood is that for the prevention of this growth the entire piece must be treated. The author cites a case where beech ties 8 ft. long were treated. After treatment, these ties were sawed in the middle and used as tram ties. In other words, one end of each tram tie was the original treated end, and the other end was the part that had been sawed through and received no treatment. When inspected after about five years of service these so-called creosoted ties were found to have enormous bunches of fungi growing out at their ends. The significance of this lies in the fact that we have to deal with comparatively new points of view in treating industry, namely, the failure of the unprotected portion of the timber.

In treating paving blocks, it happens sometimes that the hardwood is thoroughly impregnated with black oil, while only a very small amount of oil gets into the sapwood. The author ascribes this not to the oil, but to the process under which the oil is injected into the block and the methods used to obtain such penetration. He believes that it is due probably entirely to the fact that the moisture contained in the sapwood prevents the proper penetration of this sapwood, while the hardwood, with a comparatively low moisture content, receives a very thorough impregnation. (*Loco*, vol. 7, no. 2, p. 122, August, 1916, 16 pp., 5 figs. *p.*)

TESTS OF FIRE RETARDENTS, WITH SPECIAL REFERENCE TO THE SHINGLE ROOF

Extracts from a bulletin by Herman and Arnold von Schrenk, comprising a report for the Engineering Bureau of the National Lumber Manufacturers' Association, Chicago.

Before beginning their investigation, the experimenters went over the numerous tests made in past years to demonstrate the efficiency of various compounds as fire-resisting materials. They found, however, that practically all of these tests have been made in an unscientific manner, and so did not permit the drawing of definite and reliable conclusions. Among other things, a point concerning which very little information of definite value is available was the permanence of fire-resistive wood, or the manner in which such wood resisted the action of wind and fire.

It was furthermore found that any discussion of the subject fell naturally into two divisions, one dealing with the problem as applied to building lumber and the other as applied to shingle roofs. The requirements for a successful fire-retardent were found to be very different for these two classes of use.

The apparatus used by the writers, and developed by the U. S. Forest Service, involved a furnace in which treated wood is tested under definite conditions identical for all the tests made. The tested sections are exposed at the same distance to a plate heated electrically to a constant temperature of 450

deg. cent. (832 deg. fahr.) The efficiency of the material tested was measured by the length of time it took, under the conditions described, to bring about ignition.

The conclusions so far reached indicate that several compounds are now available, which if properly applied will give a shingle roof a very high degree of fire resistance. These compounds have every guarantee of permanence. They are insoluble in water, and give a roof a pleasant appearance. The results indicate that there is every probability that a number of substances, not only practicable but fairly cheap, can with simple directions be applied by an ordinary house owner and give him a high degree of fire protection, whether on a roof or in a building. (*Railway Review*, vol. 50, no. 6, p. 192, August 5, 1916, 2 pp. *ep.*)

Strength and Other Properties of Concretes as Affected by the Materials and Methods of Preparation

R. J. Wig, G. M. Williams and E. R. Gates

Data of about 20,000 tests. Compressive and tensile tests were made upon mortars of different ages, including about 240 different sands and stone screenings, and compressive tests were made on concretes composed of 60 aggregates, including limestones, gravels, granites, cinders and trap rock, as well as tests of the physical properties of the sands, stone screenings and coarse aggregates. Only the conclusions of this important investigation can be reported here.

1 No standard of compressive strength can be assumed or guaranteed for concrete of any particular proportions made with any aggregate unless all the factors entering into its fabrication are controlled.

2 A concrete having a desired compressive strength is not necessarily guaranteed by a specification requiring only the use of certain types of materials in stated proportions. Only a fractional part of the desired strength may be obtained unless other factors are controlled.

3 The compressive strength of a concrete is just as much dependent upon other factors, such as careful workmanship and the use of the proper quantity of water in mixing the concrete, as it is upon the use of the proper quantity of cement.

4 The compressive strength of concrete may be reduced by the use of an excess of water in mixing to a fractional part of that which it should attain with the same materials. Too much emphasis cannot be placed upon the injurious effect of the use of excessive quantities of water in mixing concrete.

5 The compressive strength of concrete may be greatly reduced if, after fabrication, it is exposed to the sun and wind or in any relatively dry atmosphere in which it loses its moisture rapidly, even though suitable materials were used and proper methods of fabrication employed.

6 The relative compressive strength of concretes to be obtained from any given materials can be determined only by an actual test of those materials combined in a concrete.

7 Contrary to general practice and opinion, the relative value of several fine aggregates to be used in concrete cannot be determined by testing them in mortar mixtures. They must be tested in the combined state with the coarse aggregate.

8 Contrary to general practice and opinion, the relative value of several coarse aggregates to be used in concrete cannot be determined by testing them with a given sand in one arbitrarily selected proportion. They should be tested in such combination with the fine aggregate as will give maximum density, assuming the same ratio of cement to total combined aggregate.

9 No type of aggregate such as granite, gravel or limestone can be said to be generally superior to all other types. There are good and poor aggregates of each type.

10 By proper attention to methods of fabrication and curing, aggregates which appear inferior and may be available at the site of the work may give as high compressive strength in concrete as the best selected materials brought from a distance, when the latter are carelessly or improperly used.

11 Density is a good measure of the relative compressive strength of several different mixtures of the same aggregates with the same proportion of cement to total aggregate. The mixture having the highest density need not necessarily have the maximum strength, but it will have a relatively high strength.

12 Two concretes having the same density but composed of different aggregates may have widely different compressive strength.

13 There is no definite relation between the gradation of the aggregates and the compressive strength of the concrete which is applicable to any considerable number of different aggregates.

14 The gradation curve for maximum compressive strength, which is usually the same as for the maximum density, differs for each aggregate.

15 With the relative volume of fine and coarse aggregate fixed, the compressive strength of a concrete increases directly, but not in a proportionate ratio as the cement content. An increase in the ratio of cement to total fine and coarse aggregates when the relative proportions of the latter are not fixed does not necessarily result in an increase in strength, but may give even a lower strength.

16 The compressive strength of concrete composed of given materials, combined in definite proportions and fabricated and exposed under given conditions, can be determined only by testing the concrete actually prepared and treated in the prescribed manner.

17 The results included in this paper would indicate that the compressive strength of most concretes, as commercially made, can be increased 25 to 100 per cent or more by employing rigid inspection which will insure proper methods of fabrication of the materials. (*Technologic Papers of the Bureau of Standards*, no. 58, June 20, 1916, 172 pp., 44 pp. *eA.*)

The Density and Thermal Expansion of American Petroleum Oils,

H. W. Bearce and E. L. Peffer

This paper gives an account of the experimental work on which are based the expansion tables of Circular No. 57, "United States Standard Tables for Petroleum Oils." It gives a detailed description of the methods and apparatus employed in the determination of the density and thermal expansion of petroleum oils from the various oil fields of the United States. (*Bureau of Standards, Technologic Paper* no. 77, preliminary abstract.)

Foundry

A Pre-Heated Blast Cupola, J. A. Parsons

Description of a cupola in which the blast is pre-heated.

The air blast, instead of getting into contact with the bed of the coke coals, is passed through a series of tubes in the top or chimney of the cupola, and reaches the coke bed at first

only slightly warm, and after a few minutes at a temperature that melts the lead, then at a temperature that burns zinc, and, after the blast has been on say twenty minutes, at approximately one-third of the total temperature required to be imparted to the iron.

With the device under description, it is not claimed that the evolution of carbon monoxide is altered, but that when it is burned into carbon dioxide in the top of the cupola the heat then evolved (10,220 B.t.u.) is to a large extent absorbed into the blast through the tubes instead of being allowed to waste.

Among other advantages it is claimed that the furnaces can be held up temporarily by diminishing the blast, notwithstanding which the balance of the blast comes in so hot that the melting time can be reduced in proportion and without holding down the furnace unduly. This allows for a greater flexibility of operation. (*Cassier's Engineering Monthly*, vol. 50, no. 1, p. 60. July, 1916, 3 pp., 1 fig.)

CASTING 8-IN. H. E. SHELL INGOTS AND FORGING THE ROUGH SHELLS

Description of methods of casting and forging 8-in. shell blanks.

The requirements of shell specifications are quite strict, and to determine the quantity of the various materials so as to obtain certain results it is necessary to analyze first the scrap. In shell manufacture the bulk of the scrap has already been in the furnace for shell making, which makes it very much easier for the melter to calculate his charge.

In the plant to which the article mainly refers, in a 20-ton charge they use from 7000 to 7500 lb. of pig, 13,000 lb. of shell head scrap, 7600 lb. of plate scrap, and about 11,000 lb. of crop ends from the tops of the previous ingots. These, with the addition of iron ore, silicon and manganese, bring the total charge up to between 38,000 and 42,000 lb. Of the total charge of pig iron 75 per cent is placed in the furnace first, and as this begins to settle, the shell scrap, plate scrap and crop ends are added. When these have become partly melted, the remaining 25 per cent of pig is placed in the furnace. The time required to melt a charge of about 20 tons is from 4½ to 5 hr.; in addition, another hour or so elapses before the molten mass comes to a tapping condition.

When the heat is about ready, the tapping tests are made for carbon content by removing a small bar and breaking it. The trained eye of the melter tells him the amount of carbon by the exposed surface of the fracture. No chemical test is made of a charge until the metal has been poured into the molds.

The article describes in some detail the tapping and pouring of the molten metal. The tapping is done into a large ladle. The capacity of the 20-ton ladle will fill approximately 120 8-in. molds or 360 4.5-in. molds. In order to avoid any possibility of the metal freezing, it is advisable to have it very hot when working on the 4.5-in. ingots. As each ingot is poured the top surface is covered with floor sand to retain the heat and also to aid in the feeding of the metal as the billet solidifies. It requires about 10 or 20 minutes for the ingots to become solid.

When the crop ends of the ingots are cut off the billets are taken to another plant, where they are forged into the rough shell. The billets, 15 at a time, are placed in oil-burning Ferguson furnaces and are heated to about 2100 deg. fahr., this taking from 1¾ to 2 hr. When the billets are a little high in carbon they are allowed to soak a little longer, this slightly reducing the percentage of carbon.

A 350-ton Wood forging press has a capacity of approximately four hundred and fifty shells per day of 24 hr., and to maintain this production it requires the continuous operation of four 15-shell heating furnaces.

To insure satisfactory operation in forging the scale is removed from the surface of the heated billet by means of scrapers. This is not only necessary for the longer life of the dies but is essential to the uniform drawing of the shell, as the adherence of scale will often tend to produce a forging with eccentric walls.

Among other things, the article describes the preparation of the ladle and molds, ladle refitting and the operations of forging proper. (*Canadian Machinery*, vol. 16, no. 4, p. 81, July 27, 1916, 4 pp., 6 figs. *d.*)

Fuel

THE VALUE OF PEAT FUEL, AS COMPARED WITH COAL, FOR PRODUCTION OF POWER, B. F. Haanel

Discussion of the subject of peat fuel manufacture and use, with special reference to the practice of a German plant.

The most important difficulty in the manufacture of peat fuel is the reduction of moisture to a permissible amount, which means a reduction from 90 per cent to about 25 per cent.

By a brief calculation the writer shows that this cannot be done by the application of artificial heat solely, because the quantity of heat required to reduce the moisture from 90 to 25 per cent is approximately 97,000 B.t.u., while the quantity of heat available in dry peat is only about 90,000 B.t.u.

By pressing in hydraulic presses the water content of the raw peat can be reduced to about 75 per cent, but a further reduction so far could not be effected economically because part of the water in the peat is held chemically. A larger amount, however, can be extracted by the so-called "wet-carbonizing process" of Ekenburg, but up to the present time this process has not proved to be commercially feasible.

The only process that appears at present to be commercially applicable is that dependent on the sun's heat and wind for the evaporation of the moisture. The conditions under which peat fuel in the opinion of the writer can compete with coal are principally the proximity of peat deposits to points of consumption and the high cost of coal owing to distance of coal mines from points of consumption. This applies to the production of power in gas producers without by-product recovery. When the latter is considered, new factors arise which may alter the comparative value of the two fuels.

Peat can be burned as efficiently as coal in properly designed steam generators. The principal disadvantages of peat fuel are its comparatively low heating value, larger volume occupied per heat unit, and the difficulty of handling and storing the requisite quantity of fuel for a period of operation. On the other hand, the amount of ash is small.

The only large steam-power plant designed for the exclusive use of peat fuel of which the writer has any details, is that of the Siemens-Schuckert Company on the Wiesmoor, in Ostfriesland, Germany. This plant is equipped with specially designed steam generators and steam turbines and has a capacity of over 5000 h.p. The steam generators are supplied with special grates with removable bars and large combustion chambers, similar to those of the Babcock & Wilcox boilers. With peat fuel costing $1.20 per ton, the price at which it is said the German Government sells the fuel to this company under contract, the steam plant is able to generate power more cheaply

than with coal including delivery costing $3.50 per ton.

Tests conducted at this plant showed that a thermal efficiency of 73.5 per cent could be realized for the steam generator; this is equivalent to an evaporation of 3.01 kilograms of water per kilo of peat, or 3.01 pounds of water per pound of peat. The average calorific value of the peat burned was 4.824 B.t.u. per pound, which, it might be remarked, is low compared with that determined for many of the Canadian peats so far examined. The moisture content of the peat fuel, of course, varies, but an effort is made to keep the average in the vicinity of 30 per cent.

The above results cannot be realized in every-day operation. Up to the time the plant was visited by the writer, it had been possible to attain a consumption of 2.4 to 2.8 kilos (5.28 to 6.16 pounds) per kilowatt-hour in rare and isolated cases. A consumption of 2.4 kilos (5.28 pounds) of peat has in fact been obtained. In wet weather the fuel consumption averages 3 kilos (6.6 pounds) per kilowatt-hour.

If the cost of peat per ton is taken as 5 marks ($1.20), a fuel consumption of 2.4 to 2.8 kilos (5.28 to 6.16 pounds) per kilowatt-hour would cost 0.3 to 0.35 cent per kilowatt, which at that place would be about the same price as when coal is burned.

From the foregoing it will be seen that peat fuel can be utilized in competition with coal for the production of power in steam plants, but only when the most rigid economies are introduced both in the manufacturing and handling of the peat fuel and in the conversion of its heat energy into useful work. (*Journal of the American Peat Society*, vol. 9, no. 2, p. 47, April, 1916, 15 pp., 5 figs. *dg.*)

Hydraulics

Cycloidal Curve Expressing the Law of Distribution of Velocities in Flow of Water in Pipes, M. Moignié

Discussion and experimental investigation of the distribution of velocities of flow of water in pipes, having for its purpose to prove that when water flows through pipes without the formation of eddies, the law of decrease of velocity from the center outwards may be conveniently expressed by a cycloidal curve.

The author refers the cycloidal curve to its axis and a line tangent to it at the apex.

Let O y (Fig. 2) be the axis of a pipe of radius $B\ A = R$. Let us now plot the semi-cycloidal $O\ P\ A$ generated by the point P of the periphery of the circle of radius R/π rolling without friction along the radius $B\ A$.

When expressed as a function of the variable angle $P\ C\ E = \theta$ which the radius $C\ P$ makes with the axis $O\ y$, the coördinates of the point P may be written as:

$$X = \frac{R}{\pi}(\theta + \sin\theta);\quad y = \frac{R}{\pi}(1 - \cos\theta)$$

or they may be also expressed as follows: By multiplying all the ordinates by $\lambda\pi/R$, where λ is a numerical constant, we obtain the following parametric equations:

$$\begin{cases} x = \dfrac{R}{\pi}(\theta + \sin\theta) \\ y = \lambda\ (1 - \cos\theta) \end{cases}$$

which express a cycloidal curve.

In order that the last named equations express the law of decrease of velocities, it is sufficient to substitute

$$x = r, \qquad y = \frac{V - v}{U\sqrt{b}}$$

A curve proposed to express the distribution of the velocities will therefore finally be represented by the following equations:

$$\begin{cases} \dfrac{V - v}{U\sqrt{b}} = \lambda\ (1 - \cos\theta) \\ \dfrac{r}{R} = \theta + \sin\theta \end{cases}$$

where λ is a numerical coefficient which has to be determined experimentally.

The author describes then the experiments of Bazin, published in 1897, from the data of which he obtains the experimental values of $(V - v)/U$, which he expresses in the form of tables and curves. The curves are of interest in that they (there are six) form two clearly distinct groups, some of which are remarkable because of their slower decrease of velocities with the approach to the center of the tube. The author points out that this could have been foreseen because after the contraction which exists at the entrance to the tube, the relative velocities do not immediately attain the values which they attain later when a uniform flow is established. Moreover, twenty-five diameters, which was the distance from the entrance of the tube to the point at which the first series of measurements was taken, is not sufficient to eliminate the initial disturbance of flow.

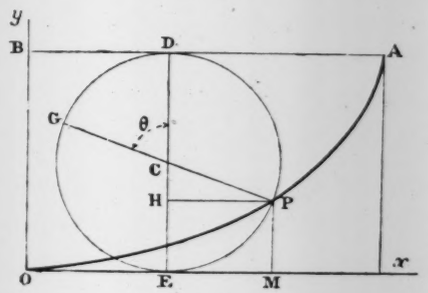


Fig. 2 Semi-Cycloidal Curve Illustrating the Law of Distribution of Velocities in the Flow of Water in Pipes

From the expression for the cycloidal curve, the author derives expressions for the mean velocity of flow. He finds values of V/U to vary from 1.1627 to 1.1667 and finds, therefore, that the value of $V/U = 1.1667$ derived from Boussinesq's formula represents very exactly the average of the experimental values obtained at one of the sections of the pipe.

The writer finally compares the ratios of maximum and minimum velocities to the mean velocity and finds for them the expressions

$$V/U = 1 + 8.93\sqrt{b},\ w/U = 1 - 14.27\sqrt{b},$$

as precise as the values obtained from the formula of Bazin and Boussinesq.

Notation:

V = velocity of the central water thread
v = velocity of a water thread at a distance r from the center of the tube
R = radius of the tube
J = gradient
U = average velocity
$b = RJ/U^2$

(*Courbe Cycloidale de Distribution des Vitesses dans les*

Tuyaux, M. Moignié, *Annales des Ponts et Chaussées*, Partie Technique, vol. 6, Tome 30, p. 303, November-December, 1915, 23 pp., 4 figs. *t.*)

Machine Parts

ANTI-FRICTION BEARINGS IN AXLE GENERATOR SERVICE, J. R. Sloan

Discussion of anti-friction bearings from the point of view of maintenance cost of axle generator service in railway lighting equipment. Proper belt operation is a somewhat difficult matter with any type of generator; particularly with the truck mounted type the high initial belt tension necessary to prevent belt slipping is often applied by careless inspectors far in excess of the amount actually required, and causes very severe loads for the pulley end bearings. This, together with the stresses due to vibrations and irregularities of road, were the chief causes of the excessively high generator maintenance cost, in 1911 and 1912 as compared with what they are now. The net generator cost per car per month was in 1911, $23.30; in 1912, $24.12 and in 1914 and 1915 respectively, $10.22 and $10.86 which reduction of cost was due practically entirely to the rather extensive application of anti-friction bearings.

Of the total, 734, there have been but 4 ball bearing failures reported or approximately ½ of 1 per cent per annum which is an extremely good showing in comparison with the frequent failures of plain bearings. In no case, however, were the armature or field coils damaged, a frequent occurrence when sleeve bearings failed and let the armature down on the pole pieces. (*Railway Electrical Engineer*, vol. 7, no. 14, p. 409, July 1916, 1 p., 1 fig., *cp.*)

APPLICATION OF ANTI-FRICTION BEARINGS, T. V. Buckwalter

Description of the installation of ball bearings on baggage trucks of a light weight design and on trucks for creosoting plants.

The baggage trucks are equipped with Timken bearings on all four wheels, the bearings being mounted to take thrust in all directions and to take the load equally. The bearings have a rating at constant normal loading of 625 lb. each and carry 545 lb. per bearing, or 87 per cent of the normal constant loading; in addition to this load due to weight, there is some thrust load taken by these bearings due to road shocks and curving but these thrust loads are considered negligible. There are no reports of failures of any of the bearings on this type of truck.

The next type described are trucks for creosoting plants. These trucks must be moved by hand with a load approximating five tons for short distances which makes the use of plain bearings inadvisable.

These trucks are made in two general types, namely tie trucks with four wheels and integral bolsters and timber trucks with four wheels and swinging bolsters, the latter to facilitate the loading of long timbers.

The bearings are of the Hyatt flexible roller type adapted to take radial load only. The thrust on the timber treating trucks, which is considerable, is taken directly on the hubs of the wheels on plain surfaces formed on the bearing housing. These bearings are loaded up to 50 per cent above their normal capacity and in the five years they have been in service (a total of 200 trucks) there are no reported failures.

No provision was made to lubricate the bearings on these trucks. The only lubrication they receive is the immersion in creosote at each treatment of their load of timber or ties. (*Railway Electrical Engineer*, vol. 7, no. 14, p. 418, July 1916, 2 pp., 5 figs. *d.*)

ANTI-FRICTION BEARINGS IN CAR LIGHTING GENERATORS

Three letters from H. C. Meloy, Engineer of Electrical Appliances on N. Y. C. Lines, West, E. C. McNab, Car Lighting Engineer of the Canadian Pacific and A. E. Voigt, Assistant Electrical Engineer, Santa Fe. All reported in favor of ball bearings as compared with sleeve bearings. The last named letter reports comparative statistical data on ball and sleeve bearing failures, with results likewise in favor of ball bearings. (*Railway Electrical Engineer*, vol. 7, no. 14, p. 408, July 1916, 1 p., *ps.*)

Machine Shop

ALUMINUM WELDING, Harry B. Hoover

The process of welding aluminum is somewhat difficult to learn but it can be applied to work which would be difficult to repair by any other means. The writer describes a method which after several years of successful experience he found to be the most practical.

Some of the most difficult things to contend with in aluminum welding are the rapid oxidation of the metal, the low fusion point, rapid conduction of heat, contraction and expansion, shrinkage, and in some cases warping which makes it difficult to keep the work in perfect alignment.

As regards oxidation, the writer points out that any fluxes used must be chemically active and then one has to reckon with the after-effects of the flux which sometimes do not develop until some time after. It is therefore important that the work be thoroughly brushed in boiling water to remove remnants of the flux and prevent chemical action after the welding has been done. At times the use of flux is exceptionally difficult. It is, however, necessary in sheet aluminum work.

For practical purposes the puddling system is by far the best. This is done by the use of a paddle made from a small steel rod flattened at one end like a flat screwdriver and ground or filed off smooth, the edges being left sharp. As aluminum, unlike some other metals, does not change color when it becomes hot it is necessary to watch it very closely during the process of welding and at the time when the edges begin to fuse the paddle is used to puddle them together.

The contraction and expansion of aluminum are greater than of any other metal and if they are not properly taken care of a case which is being welded will warp or shrink out of alignment to such an extent that it is entirely useless. The shrinkage and warping may be taken care of to a certain extent by proper preheating say by a preheating torch. The author describes in detail several cases of typical welding. (*Machinery*, vol. 22, no. 12, p. 1032, August 1916, 4 pp., 5 figs. *dp.*)

DRAWING METAL BY HYDRAULIC METHOD, G. R. Smith

The principal difficulty encountered in drawing metal over dies in heavy presses is the tendency for the metal to fail at certain points where excessive stresses are produced by the stretching action of the dies. This makes it necessary to use only sheet metal of high tensile strength, which adds to the cost of production.

The present article describes a method of hydraulic shell-drawing which is claimed to overcome this difficulty. Two blanks are clamped at the edges between two dies. When hydraulic pressure is applied between them, the blanks are forced outward to the contour of the dies. Since the metal is

only held at its outer edge, practically the entire area is subject to stretch. Thus the stresses are distributed evenly and excessive local strains are eliminated.

It is claimed that the initial cost of the hydraulic equipment for the presses is low, while the cost of maintenance is very materially reduced through the fact that dies are not subject to the heavy wear imposed by impact as in the usual type of presses. (*The Iron Trade Review,* vol. 59, no. 5, p. 213, August 3, 1916, 1 p., 2 figs. *d.*)

HYDRAULIC SYSTEM IN MODERN SHELL PLANT, F. L. Prentiss

Description of the pumping equipment and other features in the new shop of the Hydraulic Press Steel Co. of Cleveland, O.

The plant has been built mainly to take care of orders for shell forging, but has been laid out with the view of converting it to other hydraulic press work as soon as the demand for shell forgings ceases. The shell plant is equipped with six units, each consisting of a piercing and drawing press, and its capacity is for a daily output of 15,000 3-in. shrapnel forgings.

The pumps are located in a row along one side of the pump house. One attendant and two oilers are able to take care of the entire pumping equipment.

Overhead piping is eliminated by having the water supply lines run from the header through the shop in tunnels. The water is carried from the high-pressure header through a 10-in. main pressure line, from which 8-in. branch lines are carried through the shop, each branch line serving three units and each unit consisting of a piercing and drawing press. One main shut-off valve is provided on the 10-in. line, and there is another valve for each press with an 8-in. line. This small line is provided with a shock valve which acts as an equalizer, and a three-way operating valve. The shock valve takes the place of the usual overflow chamber and has the advantage of taking less space than is required for the latter.

Among other things an equalizing device is being provided to insure the equal travel of all accumulators, giving a high-pressure water capacity of 1500 gal. per minute. The maximum intensified pressure used in the plant is 6000 lb. per square foot.

Specially designed tool boxes are provided for tools used in changing the tools in the presses. These boxes have three drawers each. The plant operates at three 8 hr. turns and a tool box is provided for each press, each of the foremen having a separate set of tools which he keeps under lock in one of the drawers. In this way the man in charge of the press gang is responsible for his own tools, and the trouble of having tools lost or mislaid when handled by separate sets of men is eliminated. (The *Iron Age,* vol. 98, no. 5, p. 231, August 3, 1916, 4 pp., 4 figs. *d.*)

PRODUCTION, PROPERTIES AND USE OF THERMALENE

Thermalene is a new gas which may be used for welding, heating, lighting and other purposes. It is a combination produced by the decomposition of calcium carbide and hydrocarbon oils, the heat generated by the carbide being used to vaporize the oil. It is a discovery of K. F. L. Wolf, of Zurich, Switzerland.

The article describes the method of producing the gas. The physical properties of the gas are different from those of either oil gas or acetylene. Its density is 1.1, taking air as unity. Its specific heat is a little over one-eighth that of acetylene. Thermalene liquifies at a pressure of between 1400 and 1500 lb. per sq. in. at room temperatures, and in its liquid state is not explosive. The maximum flame temperature has been found to be about 6500 degrees. It does not explode as readily as acetylene and so can be mixed with greater proportions of air. The upper and lower explosive limits are 12 per cent and 30 per cent.

When used for welding thermalene does not require an excess of oxygen, and for this reason does not absorb carbon from the iron. The flame, therefore, produces a soft weld, especially in cast iron. When welding with it less sparks are thrown off than when using acetylene. It can be also used at a lower pressure, owing to its higher specific gravity.

The torches used were also designed by K. F. L. Wolf, and under all sorts of tests showed no tendency to flash back. The construction of these torches is shown in detail in Fig 3. The oxygen nozzle is at *C*. Screens are placed at *D*. No flashback into the oxygen nozzle can occur in this type of torch. The gas chamber is comparatively large, while the orifice leading from the gas chamber to the mixing chamber is restricted and elongated. This orifice is enlarged abruptly to the mixing chamber in the nozzle, so as to form sharp corners at *E*. The mixing chamber gradually contracts to the outer opening in the nozzle. As a result, if flashback should occur it will

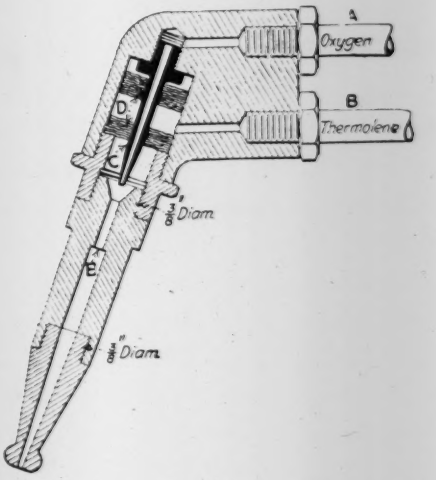


FIG. 3 WOLF TORCH FOR USE WITH THERMALENE GAS

cause an eddy at *E*, which in itself will prevent the flame from running back through the restricted channel; moreover, such propagation of the flame into the mixing chamber will cause the gas in the chamber to be pressed back by the increased expansion and pressure, so that there will be only burnt gas in the restricted channel and around the oxygen tip. Further, the pure oxygen discharged from the nozzle of *C* will cool off and blow out the flame. The result is that the flame will die out in the restricted channel between the gas and mixing chambers, so that a cutting flame is never formed at the oxygen nozzle. It is necessary, however, that these torches should be properly proportioned to obtain the desired results.

Table 1 gives a good idea of the amount of thermalene and oxygen used per hour for different thicknesses of metal, the torch being fitted with the proper nozzle in each case. (*American Machinist,* vol. 45, no. 6, p. 221, August 10, 1916, 5 pp., 10 figs. *d.*)

METHODS USED IN MACHINING AN AEROPLANE CYLINDER, Robert Mawson

Description of tools and methods used in machining the cylinders for the eight- and twelve-cylinder Ashmusen aero-

TABLE 1 TABLE OF QUANTITIES OF THERMALENE AND OXYGEN USED PER HOUR IN WELDING OPERATIONS

Tip No.	Thickness of Metal in Inches	Consumption of Thermalene, Cu. Ft.	Consumption of Oxygen with Thermalene, Cu. Ft.	Oxygen Pressure, with Thermalene, Lb. per Sq. In.
1	1/16 to 1/8	2.15	2.55	1.0
2	1/8 to 3/16	3.32	3.99	2½ to 3
3	3/16 to 1/4	5.51	6.52	3 to 3½
4	1/4 to 5/16	8.29	10.11	3½ to 4½
5	5/16 to 3/8	11.78	14.21	5 to 5½
6	3/8 to 7/16	16.48	20.10	6½ to 7½
7	7/16 to 5/8	21.40	27.51	10 to 11
8	5/8 to 3/4	25.00	35.01	11 to 12
9	3/4 to 7/8	33.60	54.21	15
10	7/8 to 1¼	48.05	75.30	20 to 22
11	1¼ to 1⅝	70.35	101.62	25 to 28
12	1⅝ to 2	91.10	159.20	25 to 30

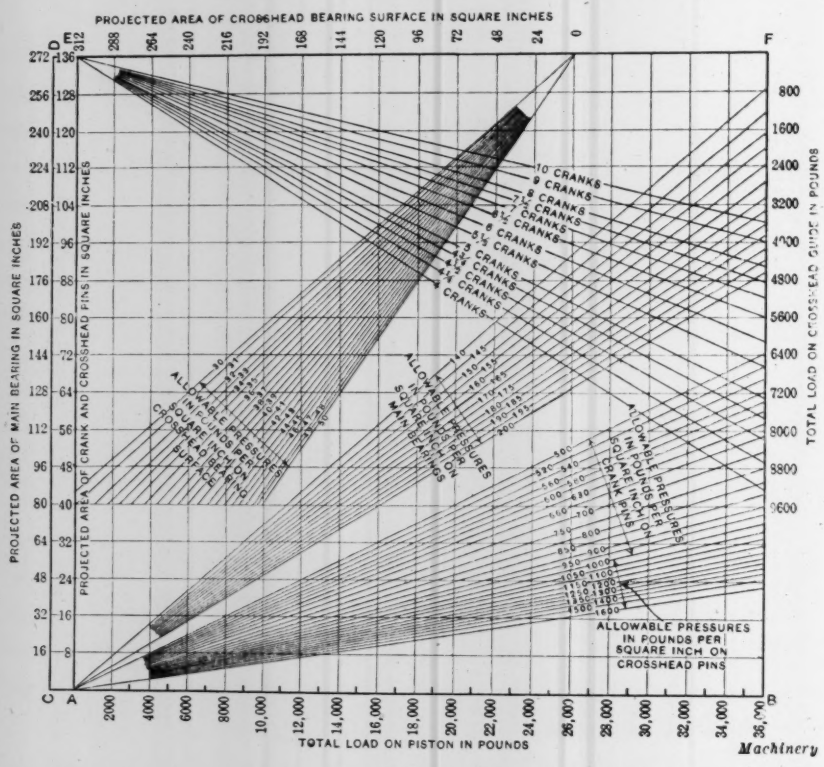

PROJECTED AREA OF CROSSHEAD BEARING SURFACE IN SQUARE INCHES
PROJECTED AREA OF MAIN BEARING IN SQUARE INCHES
PROJECTED AREA OF CRANK AND CROSSHEAD PINS IN SQUARE INCHES
TOTAL LOAD ON CROSSHEAD GUIDE IN POUNDS
TOTAL LOAD ON PISTON IN POUNDS
10 CRANKS
9 CRANKS
8½ CRANKS
8 CRANKS
7½ CRANKS
7 CRANKS
6½ CRANKS
6 CRANKS
5½ CRANKS
5 CRANKS
4½ CRANKS
4 CRANKS
ALLOWABLE PRESSURES IN POUNDS PER SQUARE INCH ON CROSSHEAD BEARING SURFACE
ALLOWABLE PRESSURES IN POUNDS PER SQUARE INCH ON MAIN BEARINGS
ALLOWABLE PRESSURES IN POUNDS PER SQUARE INCH ON CRANK PINS
ALLOWABLE PRESSURES IN POUNDS PER SQUARE INCH ON CROSSHEAD PINS
Machinery

FIG. 4 CHART FOR USE IN RAPIDLY DETERMINING LOADS ON IMPORTANT ENGINE FRAME MEMBERS

plane engines made by the Ashmusen Manufacturing Company, Providence, R. I.

The article briefly describes and illustrates the tools used, and also the main operations, step by step. (*American Machinist,* vol. 45, no. 6, p. 230, August 10, 1916, 2 pp., 6 figs. and one plate. *d.*)

PURELY-HYDRAULIC AND STEAM-HYDRAULIC FORGING OF STEEL COMPARED, A. Myslin

The paper compares the purely hydraulic process of forging with the steam-hydraulic from the point of view of consumption of power per unit of weight of output. The investigation is based on the working of a steam-hydraulic forging press at the Upper Toorin works in northeastern Russia.

The author had before him a purely hydraulic press of 90 tons capacity, working with an accumulator and forging sheet plates with an output of about 17 tons daily.

The steam-hydraulic press has a capacity of 5000 tons and is used for forging 6-in. trotyl shells from ½-ton cropped steel ingots. This press has a daily output of about 35 tons.

Sometime near the beginning of the year 1914 a thorough stop-watch study of movements was made at the plant as a preliminary to the introduction of the Taylor system of shop management. At that time the following table was obtained covering the forging of one 50-pood (1 pood = 36 lb.) ingot having after cropping a weight of 35 poods. This ingot is forged into a 6-in. billet having a section of the shape of an octagon inscribed into a circle of 167 mm. (6.57 in.).

Time Necessary for Forging	*Minutes*
1. Withdrawing ingot from furnace, conveying it to the press and locating it in the correct position for forging	1.5
2. Time required for the forging of the ingot	10.75
3. Time required for straightening	3.5
4. Time consumed in the interruption between the end of the forging of one ingot and the beginning of the withdrawing from the furnace of the next one (during this time some of the men are occupied in taking the ingot out from the press for conveying it to the sand bath)	1.5
5. Time lost by the men in changing the hammer heads and falls and tightening them up (average per forging)	5
6. Time lost by the men because of trouble with the cranes (average per forging)	0.5
Total time necessary for forging one ingot under normal conditions	22.75

At present the works have reached the stage of forging 21 ingots in an eight-hour shift.

The article gives a detailed account of the steam consumption for the forging. (*Sravneniye rabot kovki chistahydravlicheskava kovochnava, v smysle raskhoda energiyi na pood godnava prodookta i raboty parohydravlicheskikh pressov i detalnoye izlsedavaniye kovki parohydravlicheskava pressa Verkhne-Toorinskava Zavoda v svyazi s raskhodom paravoy energiyi i opredeleniye poslednyava raskhoda,* Uralskiy Tekhnic, *Uralian Engineer,* in Russian, vol. 10, no. 4-5, p. 70, April-May, 1916, 8 pp., 1 plate of drawings. *ep.*)

Mechanics

CHART FOR DETERMINING ENGINE FRAME LOADS, Ernest A. Andrews

The chart shown in Fig. 4 is for finding the loads on the following members of an engine: (1) main bearings; (2) crank pins and crosshead pins; (3) crosshead guides. The horizontal line AB represents various values of the total load

on the piston in pounds; the vertical line CD indicates the projected area of the main bearings in square inches; and the horizontal line EF shows the projected area of the crosshead bearing surface in square inches.

To determine the proper area for the crosshead bearing surface it is necessary to know the ratio of the length of the connecting rod to the radius of the crank circle.

The total load on the crosshead guide is represented on line BF at the right hand margin of the chart and is found by moving across the chart to the right from the point of intersection of the piston load line and the radial line representing the ratio of connecting length to crank radius. (*Machinery*, vol. 22, no. 12, p. 1056, August 1916, 1 p., 1 fig. *d.*)

ACCELERATING CHARACTERISTICS OF CENTRIFUGAL PUMPS AND FANS, B. W. Jones

The author emphasizes how the different load characteristics affect the amount of control apparatus necessary in the case of centrifugal pumps and fans driven by electric motors.

The external conditions under which the pump may be worked may be represented by two extreme cases. First, the pump may be discharging against a very low static or actual head, the friction head being the principal factor. A pump used for dredging is a very good example of this condition. Here the pump starts discharging at a very low speed and the speed torque requirements of the driving motor are shown in Fig. 5, curve A. This is the worst starting condition and requires the largest amount of control apparatus to keep the starting current peaks below a required amount. The second extreme case to be considered is that of a pump discharging against a very high static or actual head, the friction head being the minor factor. A good example of this condition is a centrifugal pump used for pumping water out of a deep mine where the lift is several hundred feet. A check valve or a foot valve is placed in the pipe line and this is seated when the pump is at rest. The motor speed at which this valve will open depends upon whether the pump has a flat or a steep characteristic curve. If this valve or the discharge opening be kept closed, then the speed-torque characteristic of the driving motor during starting is shown in Fig. 5, curve B.

What has been said of centrifugal pumps starting up under various external conditions holds true with proper variations for centrifugal fans. Hence it is not sufficient information for the industrial control engineer to know that the motor is to start a centrifugal pump or fan. The conditions under which they will accelerate should also be known. Without this information it is necessary to design the control equipment to meet the worst conditions whereas if the necessary details were known the equipment might be made to accelerate under the most favorable conditions. (*General Electric Review*, vol. 19, no. 8, p. 703, August 1916, 3 pp., 4 figs. *p.*)

Mechanics of Materials

ON TWO FUNDAMENTAL PROBLEMS IN THE THEORY OF ELASTICITY, C. E. Weatherburn

The writer shows how the theory of vector integral equations which was presented by him some time ago in the Transactions of the Cambridge Philosophical Society, may be directly applied to the solution of the fundamental problems of elastic equilibrium requiring the determination of the displacement at any point of an elastic body when the value of the surface displacement or that of the surface traction is known.

The author generalizes the problem by the introduction of a special parameter. Then by the use of vector analysis he constructs, from Somigliana's integrals of the equations of equilibrium, dyadics which form the basis of displacement functions whose properties exactly resemble those of ordinary simple and double stratum potentials. Corresponding theorems are established concerning the magnitude and the reality of the singular parameter values. The treatment of the fundamental problems in elasticity is thus recast.

The author derives in this way vector equations with dyadic kernels and dyadic resolvents and shows that the kernel does not become infinite of too high an order to be treated by the methods of vector integral equations. (*The London, Edinburgh and Dublin Philosophical Magazine*, vol. 32, no. 187, p. 15, July, 1916, 24 pp., *tm*)

EFFICIENCY OF UNSYMMETRICAL RIVETED JOINTS, R. N. Blackburn

Discussion of the strength of riveted joints, particularly those not symmetrical in form. Exception is taken to the rule

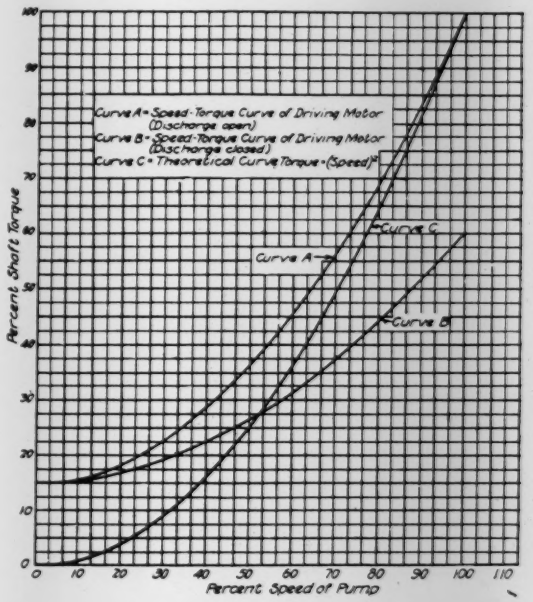


FIG. 5 PUMP CHARACTERISTIC CURVES

for such a joint, contained in the Boiler Code of the American Society of Mechanical Engineers. In the Code, examples are given of riveted joints having apparent efficiency of from 57.6 to 96.3 per cent. The writer believes that it is doubtful whether so high an efficiency as the latter figure is ever obtained, and that the actual efficiency of the joint will be less than the calculated efficiency. The apparent efficiency is calculated by certain formulæ usually based on certain assumptions that are not strictly proved. It is assumed, for example: First, that the total load is uniformly distributed over the rivets; second, that the stress in the shell plate along a line of rivet holes parallel to the joint is uniformly distributed over the net section of the plate; third, that no bending stresses are produced in the plate by the pull on the joint due to the internal pressure in the boiler.

The first assumption is seldom true, the second one never true and the third can only be true for symmetrical joints, such as butt joints with straps of equal width and with all the rivets in double shear.

In an example cited, the writer shows that if the nominal

efficiency of the rivet section, based on the assumption that the load is equally distributed over the rivets, is say 70 per cent of the strength of the solid plate, the actual efficiency is only 52.5 per cent. Further, the relative thickness of the butt strap to that of the plate materially affects the efficiency of the joint, a factor not usually taken into account in rules for calculating the efficiency of riveted joints.

A simple experiment will show the untruth of the second condition assumed in formulae for the efficiency of the riveted joints, namely, that the stress is uniformly distributed over the net section of the plate. If a narrow strip of elastic rubber be secured to a board by a nail near the end of the strip, a pencil line having previously been drawn across the rubber as shown in Fig. A, and if the strip be then pulled in the direction of the arrow, the pencil line will assume a position shown by the dotted line, clearly showing that the stress is much greater near the nail than at the outer edges of the rubber strip. Owing to the greater flexibility of rubber as compared with steel, the stress appears more concentrated near the nail than it would be in a boiler plate, but there is no essential difference in the two cases.

The writer believes that the stress in a boiler plate around

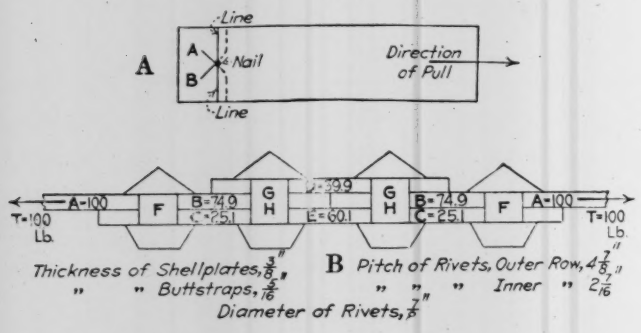


FIG. 6 A, EXPERIMENT WITH RUBBER STRIP AND NAIL TO SHOW THAT STRESS IS NOT UNIFORMLY DISTRIBUTED OVER NET SECTION OF PLATE; B, INDIA-RUBBER MODEL OF A RIVETED JOINT

(Numbers denote percentage of load carried by respective parts of joint.)

the riveted hole is so distributed that the stress at any point in a line drawn at right angles to the direction of the pull in the plate through the center of the rivet hole varies inversely as the distance of the point from the center of the rivet.

The author calls attention to the magnitude of the bending stresses produced in an unsymmetrical joint. In fact, he believes that the bending action is of more importance than the direct stress due to the pull on the plate. Other considerations affecting the strength of riveted joints are the bending stress produced by the load of the rivets and sometimes also tensile stresses. From this the writer comes to the conclusion that the nominal efficiency of riveted joints bears no exact relation to their real efficiency. He considers that the use of lap-riveted joints for large boilers is quite properly prohibited by The American Society of Mechanical Engineers, but as regards butt joints with inner and outer straps of equal width, he expresses a regret that the four examples of butt joints given in the Code to illustrate the method of calculating the efficiency of riveted joints are all unsymmetrical joints in which severe bending stresses are produced.

It occurred to the writer that a fairly correct estimate of the stresses in a riveted joint of this type could be obtained by measuring the elongation under stress of the several parts of an india-rubber model of the joint. From the measurement thus taken, the stress on each part of the joint can be readily calculated, and its efficiency determined. Several tests were made and the main results obtained are shown in Fig. B. The numbers in the sketch denote the percentage of the total load carried by the respective parts of the joint. A proposed method of estimating the stress is submitted.

The importance of this discussion lies in the fact emphasized by the writer, that unless some distinction is made between the two classes of joints, manufacturers will naturally adopt the type having the higher nominal efficiency, in spite of the fact that such efficiency is largely imaginary; and the unsymmetrical butt joint will thus become the standard used in preference to the more efficient symmetrical butt joint. (*Power*, vol. 44, no. 6, p. 203, August 8, 1916, 4 pp., 5 figs. *tc.*)

INVESTIGATION OF PLASTIC FLOW PHENOMENA, W. Trinks

The paper points out the similarity between the plastic flow of clay and that of steel, based mainly on tests described in Scientific Paper No. 278 of U. S. Bureau of Standards (E. C. Bingham).

The tests referred to in this paper were made with clay as a plastic material. Of particular interest to the steel man is the experimental determination of the relation between shearing stress and velocity of deformation. It was found that a certain minimum pressure is required to start deformation, and that velocity of deformation is proportional to the difference between actual pressure and said minimum pressure, the relation being apparently strictly linear. (*Blast Furnace and Steel Plant*, vol. 50, no. 8, p. 362, August 1916, 2 pp., 2 figs. *e.*)

Power Generation

THE ECONOMICAL PRODUCTION OF POWER FROM COKE-OVEN GAS, G. Dearle

Discussion of the general subject of coke-oven gas engines and description of a plant operated under the supervision of the author.

This installation consists of 300 to 500 b.h.p. vertical tandem gas engines, direct-coupled to 3-phase alternators generating current at a pressure of 440 volts and a frequency of 50 cycles per second.

The gas engines are of the single-acting type, 4-stroke cycle, the cylinders being so arranged that the suction stroke of one cylinder is the explosion stroke of the other cylinders on the same line. By this arrangement each crank receives one impulse per revolution, each down-stroke being a working impulse of either the upper or the lower cylinders. On the upstroke the inertia of the moving parts is absorbed by the compression of either the top or the bottom cylinder, and part of the inertia is absorbed on the downward stroke by the buffer cylinder formed under the upper piston.

By means of this arrangement the connecting rod is always in compression, and little or no strain is thrown upon the connecting rod bolts. This is an important feature, as, according to the reports of the various insurance companies, more breakdowns to engines are caused by the failure of these bolts than by any other cause.

There are eight cylinders on each engine, the upper four having a diameter of 16.5 in. and the lower ones 15.5 in., with a stroke of 16 in. The speed is 300 r.p.m. and the full load is 500 b.h.p. The object of making the upper cylinders 1 in.

larger than the lower ones is so that the whole line of pistons may be removed together; by this arrangement the dismantling of the engine for cleaning purposes becomes very simple.

The gas supplied is obtained from a battery of 110 Otto ovens; 60 of these are waste-heat and 50 are of the regenerating type. From the former about 15 per cent of the total gas is available and from the latter about 40 per cent. The average gas pressure is approximately 10 in.

The writer emphasizes the great importance of the further purification of the gas after it leaves the by-product plant. When the gas leaves the benzole scrubbers it contains about 900 grains of sulphuretted hydrogen in every 100 cu. ft. If this sulphuretted hydrogen were allowed to go through the engines, a considerable amount of trouble would be experienced. The moisture in the exhaust gases condenses as the engine cools down, and there immediately forms sulphuric acid which, in its turn, would attack the inside of the cylinders and the exhaust valves.

A further effect is that the presence of sulphur causes a certain amount of pre-ignition of the charge during the compression stroke. A possible reason for this is that the presence of a small portion of the sulphuretted hydrogen acts as an igniter, it being more liable than the rest of the gas to spontaneous combustion under compression.

The gas is therefore purified by oxide of iron in a set of four purifiers of the Wilbourne type, each 20 ft. square by 5 ft. deep. The boxes hold about 30 tons of oxide in two tiers of ordinary grids. These boxes are worked on what is known as the "backward rotation" principle. Air to the extent of 2½ or 3 per cent is drawn in at the exhauster, and this air supply plays a very important part in the re-vivifying of the oxide in the purifiers; prior to the introduction of this air the oxide in the purifiers was changed at the rate of one box for every four weeks. After the introduction of the air, the period between the changes was extended from four weeks to four months. The total sulphur contained in the gas after passing the purifiers is less than 50 grains per 100 cu. ft., and the further advantage of the purifiers is that they eliminate absolutely the last traces of any tar which may be left in the gas after passing the benzole scrubbers.

During the initial running of the plant, some trouble was experienced due to the difficulty of obtaining satisfactory mixing of the gas and air. The usual method has been to dilute the mixture with a certain amount of exhaust gas. The writer considered this method somewhat inefficient and resorted to the following expedient:

The main gas pipe to each engine was reduced for a distance of about 10 ft. to an internal diameter of 2½ in., and on reaching the engine was led into the mixing chamber for a distance of about 6 in. Entering the mixing chamber at right angles to this pipe, and about 3 in. above its end, was an auxiliary air supply controlled by a diaphragm governor. The gas admitted through the mixing chamber was then diluted by a certain quantity of air. A further air supply, controlled by a hand lever from the driving platform, was led direct into the chamber of the governor valve where the diluted gas and air met. After passing through the chamber of the governor valve the mixture was given a rotatory motion by means of a set of vanes, and was also very thoroughly mixed by being passed through a set of perforated plates. With this device over-heating or pre-ignition were eliminated and the engines could be run up to and above their rated capacity without trouble.

During March, 1914, a maximum of 15 million cu. ft. was used. During that period the author had been unable to pay the necessary attention to the question of gas consumption. The matter was then taken up and by regular analyses of the exhaust gases combined with instructions to the drivers to drive by the pressure gage, the gas consumption was reduced to 12½ million cu. ft. at the end of May, and was still further reduced later on, the load remaining approximately the same. The present consumption is approximately 39 cu. ft. per kw.-hour. For the most tried part of a gas engine of the type described, the exhaust valve, nickel steel was found to be the best material. (*The Journal of the Institution of Electrical Engineers*, vol. 54, no. 260, p. 646, June 1916, 10 pp., 2 figs. *de.*)

How to Select Prime Movers for Industrial Electrical Generating Plants, H. T. Luscomb

Discussion of the merits of Corliss engines, newer types of small steam units, producer-gas engines and various types of oil engines, all with a view to service in isolated-plant installations. The discussion is accompanied by tables obtained from actual tests of representative installations.

The writer emphasizes the fact that in considering the advisability of any type of prime mover there are two distinct phases to the question: First, the handling of the engine itself, and second, the conditions under which it is operated. There are no "fool-proof" machines, and any engine can fail if it does not get proper care. Certain types of engines are, however, more dependent upon attention for successful operation than are others. Thus, a producer-gas plant requires more diversified skill in handling than does a steam engine.

The ordinary piston or slide-valve high-speed engine and medium-size turbine with generator and necessary piping, wiring, switchboard, foundations and erection charges, cost from $50 to $90 per kilowatt of generator capacity, with a tendency to be considerably higher at the present time; for Corliss and four-valve medium- and low-speed engines, similar prices run from $75 to $100 per kilowatt of generator capacity.

Certain types of steam engines, comparatively new in this country, such as the uniflow, poppet-valve and locomobile, show high steam economies. The poppet-valve in particular, which is very popular in large plants in Europe, allows the use of superheated steam at high pressure and shows low steam consumption, but both the poppet-valve and the uniflow engines operate most economically at steam pressures higher than those generally found in isolated plants. As to cost, a recent installation of these engines consisting of three units, aggregating about 800 kilowatts, cost for the engines alone approximately $18 per kilowatt. The uniflow type costs considerably more than the Corliss type. A 140-kilowatt unit recently installed in a plant near New York cost $5000 for the engine alone, or $36 per kilowatt.

The locomobile unit is a self-contained power plant comprising boiler, superheater, preheater and compound-condensing engine, condenser, soot blower and feed heater. The guaranteed coal economy is exceptionally low. The cost varies from $79 for a unit of 300 kilowatts to $102 for one of 50 kilowatts.

In general, where any considerable proportion of the exhaust steam can be utilized, the amount of steam charged to the generation of electrical energy is little less with the uniflow, poppet-valve or Corliss engine than with the high-speed slide-valve engine. The author gives a comparison of two cases which show how the question of utilization of the exhaust steam affects the prospective economy from the prime mover selected.

The writer is anything but optimistic about producer-gas

installations for isolated plants. Since the first producer-gas electric plant was installed in New York City, about fourteen years ago, thirteen other plants have been added, and of them only four plants appear to be operating satisfactorily and are reliable enough to be depended upon exclusively. The main trouble with producer-gas plants seems to be with attendance.

The writer calls attention to the very important fact that in most factories the cost of power is a very small percentage of the cost of the finished product, while a shutdown, even for a short time, is usually an extremely costly matter. For this reason owners prefer comparative security from breakdown, even at some slight increase in the cost of power. The writer gives operating data obtained from three producer-gas electrical plants in New York City, together with a brief description of the apparatus installed in each.

In each of these three plants, which probably represent the best producer-gas practice, the reported operating cost per kilowatt hour is extremely low, ranging from 0.7 cent in the largest plant with 24-hr. operation to 1.48 cents in the smallest plant operated on a 12-hr. schedule, while the total costs,

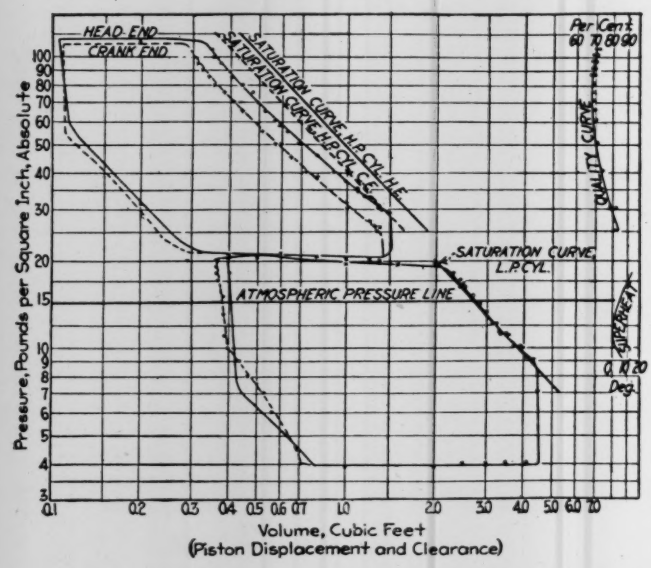


FIG. 7A AVERAGE DIAGRAMS PLOTTED TO LOGARITHMIC SCALE

including fixed charges, range from 1.14 to 2.54 cents per kilowatt-hour. In this case, however, the amount of labor charged against the producer-gas plant is exceptionally low on account of various individual conditions.

The article concludes with the discussion of oil engines for isolated plants. (*The Engineering Magazine,* vol. 51, no. 5, p. 705, August, 1916, 12 pp. 2 figs. *cps.*)

Steam Engineering

A STUDY OF INDICATOR DIAGRAMS FROM A COMPOUND CORLISS ENGINE, Professor Victor R. Gage

Data of tests made upon high and intermediate cylinders of a triple-expansion Corliss engine with a view to obtaining a series of average indicator diagrams together with saturation and superheat curves.

The interest of the tests lies in the fact that the diagrams taken from the engine at comparatively light load show that the logarithmic analysis cannot be applied under all conditions. On the logarithmic *PV* diagram, Fig. 7A, the expansion lines are not straight but curved. The curved form of the expansion lines might be attributed to leakage or possibly to faulty application of the indicators. Neither of these explanations, however, seems logical in this case, and the probable explanation is cylinder condensation and re-evaporation. The saturation curves are straight lines within the limits of the pressure range of the diagrams. If expansion lines also had this same form of equation and n (in equation $PV^n = K$) had the same numerical value, the two lines would be parallel or coincident and the quality or condition of the steam would remain unchanged during expansion.

If thermal equilibrium between the steam and the surfaces does not occur until some point on the expansion line is reached, it is not possible for the expansion line to plot as a straight line upon the logarithmic diagram. This point of thermal equilibrium and the general behavior of the steam during expansion are shown readily if the temperature-entropy diagram is employed.

On the temperature-entropy diagram, as plotted for this test, only the expansion lines appear, as well as the condition of the steam supplied and exhausted from each cylinder. (See Fig. B.) That portion of the expansion line which is of con-

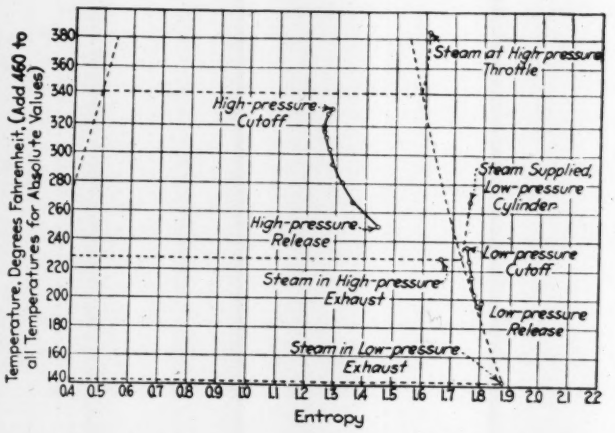


FIG. 7B TEMPERATURE-ENTROPY APPLIED TO DIAGRAMS

stant entropy (vertical) indicates the period of thermal equilibrium during which the net interchange of heat between the steam and the surface is zero. From the high-pressure cut-off to the point of equilibrium the expansion line slopes downward and to the left, with entropy decreasing, indicating transfer of heat from the steam to the surface, continuing below this point to release the transfer is in the opposite direction. The quantity of heat transferred per pound of steam may be obtained by evaluating the area under the selected portion of the expansion line down to absolute zero.

There is a slight inherent error in computing the heat interchanges in this manner. The values of entropy are based upon the total energy required to bring 1 lb. of water to the condition shown by a point on the diagram. When the cylinder is a closed vessel, the only heat energy available to do the work is the "intrinsic" or "internal" energy of the steam. Thus the heat interchanges as computed from the temperature-entropy diagram are based upon "total energy," whereas when computed by means of Hirn's analysis, only the "intrinsic" energy is used. Numerically the errors introduced in this way are probably not greater than the experimental errors. (*Power, vol.* 44, no. 6, p. 196, August 8, 1916, 2 pp., 4 figs. *et.*)

UNIFORM BOILER LAWS

A Power Show was held at Montreal during the week of July 24th.

One of the exhibits in the show was a complete set of forms, application blanks, blueprints, forms relating to boilers of all descriptions, piping plans, drawings and forms relating to boiler accessories, gages, valves, etc. In this connection it is stated that there is now a possibility that Quebec will join with British Columbia, Alberta, Saskatchewan and Ontario in having a uniform boiler inspection law. (*The Canadian Manufacturer*, vol. 36, no. 8, p. 23, August, 1916, 1 p. *g.*)

COMPOUNDING AND SUPERHEATING ON FRENCH RAILROADS, L. Baclé

The article discusses the economies of fuel utilization in France through the use of compounding and superheating on railroads, and among other things gives a brief history of compounding on railroads in France. It is based on the information contained in *Questionnaire sur la Construction et la Conduite des Locomotives à Vapeur*, by Herdner.

The article contains an interesting calculation of the amount of coal saved by the French railroads through the use of compounding and superheating. This saving as compared with the amount consumed in saturated-steam operation is from fifteen to twenty per cent. The author takes 17.5 per cent as an average of saving. On January 1, 1914, there were on the French trunk lines 13,691 locomotives, of which 5751 were equipped with either compounding or superheating or both of them simultaneously.

Locomotives so equipped made in the course of the year runs amounting to a total of about 300 million kilometers (roughly 200 million miles).

The coal consumption of modern locomotives on the Midi railway system (one of the most important French railroad companies) amounts to about 15.67 kg. per kilometer. Locomotives having the same output but working with saturated steam and without compounding would, therefore, under the same conditions of service, consume about 19 kg., or an excess of about 3.33 kg. per kilometer.

Applying this calculation to the entire system of French trunk lines with their total runs of 300 million kilometers, one gets a saving of about one million metric tons per year.

In view of the fact that the greater part of the coal consumed on French railroads comes from England, the importance of this saving becomes especially great at the present time and with the present scarcity of bottoms. The writer shows further that it would require the work of twenty coal carriers for a year to transport a million of tons from Cardiff to France, to which must be added the additional work of the railroads. (*Le Génie Civil*, vol. 69, no. 4, p. 54, July 22, 1916, 3 pp. *gs.*)

Testing Methods

TESTING MALLEABLE AND CAST STEEL, Andrew Harley

The paper is an address delivered before the Birmingham Branch of the British Foundrymen's Association on December 4, 1915. What the author has to say applies more particularly to the production of light castings in malleable iron and mild steel such as are made for the automobile and cycle trade.

In the production of malleable a uniform composition in the hard state is of the utmost importance. Irregularities in the hard metal lead to most of the difficulties in annealing. The writer used the following means to obtain the control of the composition of the molten metal, confining himself mainly to the question of the raw materials.

Pig iron is bought to specification and adequately checked, each separate consignment being given a reference number used in all subsequent records. Scrap is graded according to analysis, the silicon content being sufficient as a rule. As a certain portion of the metal is of necessity melted over and over again, scrap from one mix is accumulated so long as that particular mix is in use. If the silicon has been kept fairly regular, this heap of scrap can be safely incorporated in the mix at a subsequent date.

Coke of the best quality must be used, with sulphur as low as possible. Allowances must be made for the changes that take place in the composition of the metal during the melt. With silicon, for instance, the loss in the writer's practice at the beginning was 0.23 per cent. This would diminish fairly regularly until 0.14 per cent only was recorded. Then just at the end there was a sudden jump back to 0.21 per cent. Sulphur acts in nearly the same way; at the beginning there was an increase of 0.07 per cent, but towards the end this was reduced to 0.003 per cent.

With reference to soaking, theoretically a continuous fire is no doubt possible, but practically soaking is considered advantageous. The size and shape of the pans, strength of ore used, temperature and time taken, must be all adjusted to the end of establishing an equilibrium. The writer in his works uses gas-fired round ovens and makes his own pans (a pan should be made of metal which resists annealing) and the analysis of good annealing ore should be as follows: ferric oxide, 84 to 90 per cent; silica, 8 to 13 per cent; lime should be absent; ferrous oxide, not more than 1 per cent.

The paper is accompanied by illustrations showing, among other things, the shrinkage of malleable iron. While this in the white casting only varies slightly in low and high silicon iron, the annealing produces a further shrinkage in the low silicon and an expansion in the high silicon iron, a fact of the utmost importance both to pattern-makers and molders. Any cast malleable of high silicon content, in which a large amount of carbon is left in the graphitic and combined form, is unsuitable. Even a black heart malleable containing no combined carbon is hardened considerably after quenching.

As regards quenching, the author points out that where oil quenching is resorted to it is advisable that it be followed by a tempering treatment. The lead bath is the most effective method of performing this operation, and five hours at a temperature of 550-570 deg. is a suitable treatment. (*The Iron Trade Review*, vol. 59, no. 3, p. 121, July 20, 1916, 7 pp., 25 figs. *epA.*)

PRACTICAL METHODS FOR TESTING FIRE BRICK, C. E. Nesbit and M. L. Bell

Paper outlining conditions, apparatus and findings for various methods of determining brick qualities.

Previous tests have shown that bricks are not always the same at both ends. *Spalling* was next studied. In brick work such a condition is usually the result of thermal changes, often accelerated by mechanical pinching.

After trying various tests, it was decided to place the brick to be tested in the wall of the furnace so that only one end was exposed. The testing temperature was 1350 deg. cent.; time of heating, one hour, and cooling in water for three minutes. It was found that to produce a measurable spall ten operations are necessary.

The *slagging test* is important because failure of brickwork due to the corrosive action of slags is more prevalent than from any other cause. Experiments were made to determine the effect of fineness of the slag, time of exposure to heat and the effect of destroying the surface texture by drilling.

A *compression test* was made to determine the ability of brickwork to stand up under loads when highly heated. A comparative test, consisting of a modified Brinell ball test, was made by heating the brick to 1350 deg. cent., removing from the furnace and then forcing a 2½-in. steel ball into the brick under a pressure of 1600 pounds.

As a result of a large number of tests, it was found that firebricks tend to group themselves according to density. In general, all other factors being equal, bricks of high density have the most desirable qualities, namely, least abrasion, good resistance to slag and least compression.

An appendix describes in detail the apparatus and methods used in the tests. (*Blast Furnace and Steel Plant*, vol. 50, no. 8, p. 369, August 1916, 5 pp., 3 figs., end of serial article. *dep.*)

Testing Non-Ferrous Metals for Hardness.

Hugo Friedmann

Discussion of the application of the Brinell method in regulating methods of manufacture of non-ferrous metal products.

It is difficult to secure accurate results from hardness tests of castings as ordinary castings of brass, aluminum or bronze which have not been subjected to some mechanical treatment do not show clearly defined circular impressions when it is attempted to determine their hardness by the Brinell method. The circumference of the impression is irregular, making it a difficult matter to measure the diameter accurately. A microscopic investigation carried out by the writer failed to reveal any relation between the irregularities of the outline of the impression and the crystalline structure of the metal, and it seems likely that the indentations in the outline of the impression are caused by minute holes in the metal rather than by crystalline structure.

In addition to that, unless the metal is annealed, hardness tests on castings are likely to show varying results on different parts of the same casting owing to the differences in the speed at which the metal cooled. Hence only information regarding the general characteristics of the metal can be secured by hardness tests of castings. On the other hand, where castings of similar appearance but composed of different metal mixtures have been accidentally mixed, the application of the hardness test enables one to rapidly sort them out.

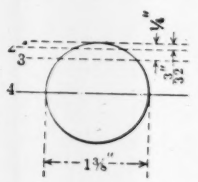
A useful application of the hardness test of non-ferrous metals is in the investigation of the influence of mechanical and thermal treatment on such materials. Hardness tests may also be profitably employed as a means of guidance in the purchase of factory supplies. For instance, sheet metal is frequently ordered in various degrees of stiffness. If complete standards are established a hardness test will definitely indicate whether the material meets the required standard.

Another application of the hardness test is shown by the following. The diameter of a rod of electrolytic copper was reduced by cold drawing from 1½ in. to 1⅜ in., then it was tested at different distances below the surface, as shown in the diagram of Table 2. The results clearly show that the drawing operation had the greatest effect on the physical characteristics of the metal near the surface of the rod, but that even a comparatively slight reduction of the diameter by drawing, as in the present case, does affect the properties of the metal at the center of the bar. The difference between the properties of the metal at different distances from the surface cannot readily be determined by other methods, as shown from the results of the following experiments. Standard tensile bars were taken from the same copper rod and turned to diameters of 1¼ in., 1 in. and ⅝ in. respectively, the purpose being to remove different amounts of metal from the surface. It might be expected that when these bars were subjected to a tensile test they would show differences in ultimate strength, but as a matter of fact all the bars were broken by the application of the same unit stress.

There is sometimes a tendency for the hardness test impressions to be elliptical in shape rather than round. Such impressions are usually formed when the material has been subjected to severe mechanical treatment in one direction only and they are usually found in cold rolled sheet metal. The difference between the long and short axes of the impression affords an indication of the amount of cold treatment to which the metal has been subjected; for example, if an aluminum sheet shows considerable hardness it may be judged from the appearance of the impression whether it is pure hard rolled aluminum or an alloy in which the hardness is due to the chemical composition of the metal rather than to the mechanical treatment to which it has been subjected. Table 3 gives an indication as to the relation which exists between the dimensions of these elliptical impressions and the other properties of the material. It shows that the strength of the material in the direction of the fibres is less than its strength across the fibres. Similarly the larger diameter of the impression indicates a lower degree of hardness and strength and is usually found in the direction in which the rolling was done.

On the other hand experiments have shown that there is no definite relation between the hardness of the metal and its resistance to wearing by friction. (*Machinery*, vol. 22, no. 12, p. 1026, August, 1916, 3 pp., *ep.*)

TABLE 2—HARDNESS OF COPPER ROD AT DIFFERENT LEVELS, SHOWING THE EFFECT OF DRAWING.



Level No.	1	2	3	4	Test on Annealed Metal at any Level
Diameter of impression made by ball, millimeters	2.85	3.05	3.15	3.25	3.55

Machinery

TABLE 3 RELATION OF HARDNESS, TENSILE STRENGTH AND PER CENT ELONGATION, NON-FERROUS METALS

	Length of Long Axis of Elliptical Impression made by Ball, Millimeters	Tensile Strength, Pounds per Square Inch	Elongation, Per Cent
In same direction that rolling was done.....	3.55	53,480	4
In opposite direction to that in which rolling was done.....	3.42	57,680	4

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